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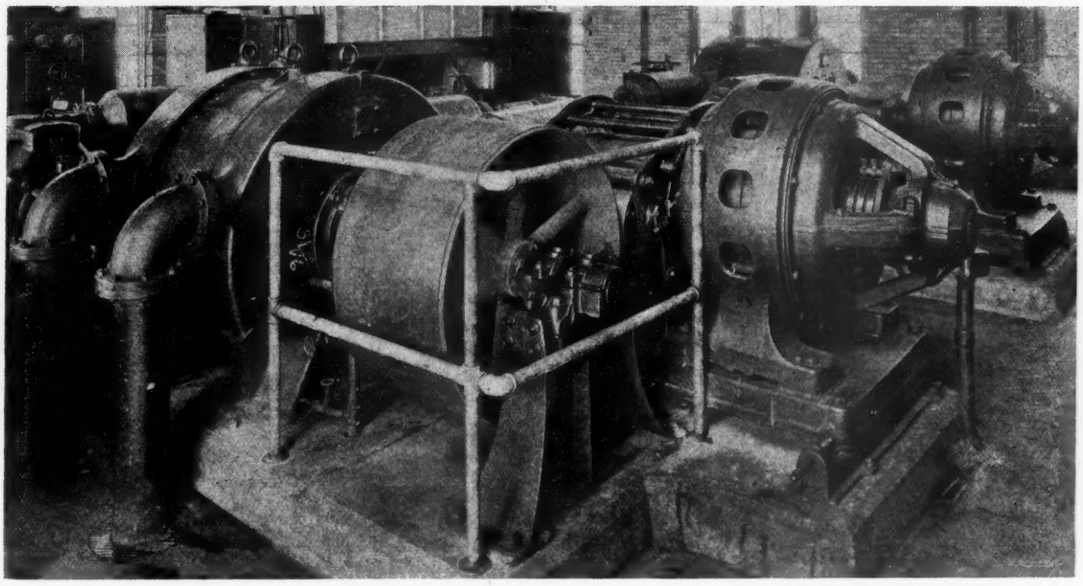

Here the motor is mounted almost as close as the equipment will permit it to be.

This motor is driving a 150-hp. Nash compressor, with the two pulleys on 49-in. centers. This Pulmax drive operates 24 hr. a day, seven days a week.

Use of Belts On Motor Drives

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A PREVIOUS article entitled "Using Flexible Couplings on Motor Drives," which appeared in the December, 1926, issue of INDUSTRIAL ENGINEER, was the first of a series on the methods of mechanically connecting a motor to a driven machine or other load. This article discussed the use of flexible coupling and clutches with particular attention to the direct-connected drive in which the driven shaft is in a straight line with the motor shaft.

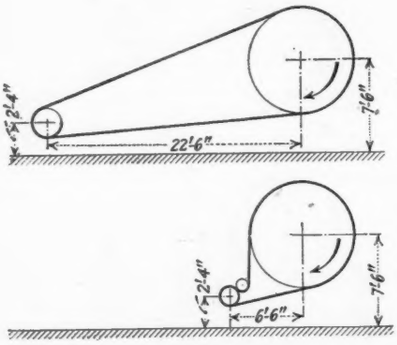
This second article continues the discussion of mechanical methods of connecting up the motor drive where the shafts are parallel, or practically so, and may be several feet apart. These mechanical connections for motor drive may be made by non-metallic links, such as ropes, and leather, fabric-base, or composition belts, or metallic links, such as chains or gears.

The present article will deal with the use of the non-metallic motor-drive links. Of these links, leather belts are the most widely used, although fabric-base and composition belts, as well as a number of belts of special construction, are used on many industrial loads. Ropes are not widely used on motor drives. Belt drives are simple, flexible, inexpensive, and elastic, and afford protection to the motor and machine in the case of overloads and shocks. To a certain extent the belt serves as a safety link for the driven machine, corresponding to the fuse for the motor. In case of excessive overload or sudden stoppage the belt slips off the pulley, usually before the machine breaks. Where the shock load is severe, as on hammer drives, belts of special construction are frequently required.

Some of the disadvantages of belt drives are that they occupy considerable space, are not positive, have relatively high maintenance cost, and are not suited to rapid reversals or other than fairly uniform speed service. The amount of floor space required

for a belt drive may be decreased by the use of short-center belt drive equipment, as is shown by two drawings on this page and many of the accompanying illustrations. This point, however, will be discussed at more length later in the article.

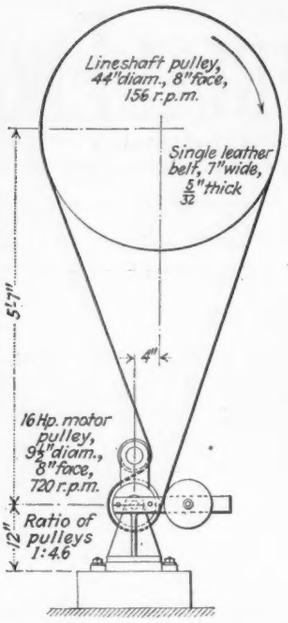
In determining the pulley sizes for a belt drive, the desired ratio and the belt speed are the determining factors. The power that can be transmitted by a belt varies with the speed and increases nearly in direct proportion until a linear speed of about 4,500 f.p.m. is reached. Beyond this, on account of increased centrifugal stresses, the effective transmitting power is reduced. Belt speeds between 2,000 and 4,000 f.p.m. are conservative and represent good operating practice. Ordinarily, about 1,000 f.p.m. is the minimum and 5,000 f.p.m. the maximum operating speed.



Floor space requirements are one of the objections of the open belt drive.

Long center distances are necessary on open drives to give sufficient arc of contact on the smaller belt pulley. By the use of the Lenix drive, this distance may be shortened considerably, as indicated, and the arc of contact increased. Also, smaller driving pulleys may be used and higher reduction ratios obtained.

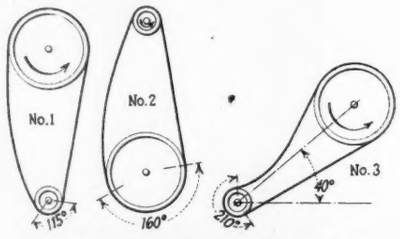
It is most economical to operate belts within the range of conservative speeds, due to lower first cost and maintenance and minimum power loss. Where very low belt speeds are necessary, wider or thicker belts must be used because the horsepower transmitted is dependent upon the speed, tension per square inch of cross-section, and width. Tension cannot be increased beyond certain values without damaging the belt; therefore, as the belt speed is increased or decreased, the width or thickness of the belt must be decreased or increased in the proper proportion if the horsepower transmitted is to remain constant. Also, there is a limit to increases in thickness because of the inefficiency of a thick belt over a small diameter pulley.



In this case a Lenix short-center drive or gravity idler improves operating conditions on a vertical motor drive.

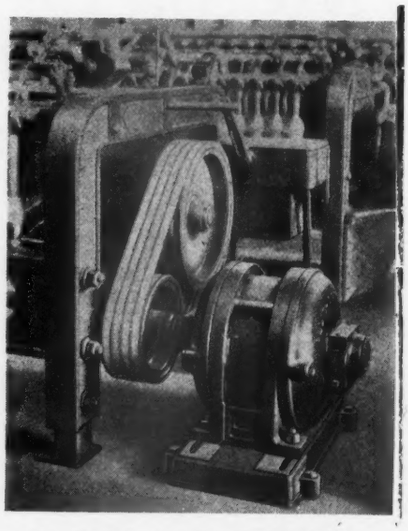
Diameters of motor pulleys, ordinarily, are kept within rather close maximum and minimum limits for each size of motor; therefore, most changes must be made in the width of the pulley. In case the center of the belt then overhangs the motor bearing a distance greater than the manufacturer has provided for in the design of the bearing, trouble may ensue. A decrease in belt contact surface, due to a decrease in pulley diameter or to short centers with high pulley ratios, would require the use of higher belt stresses due to the greater tension required to prevent slipping. There is a limit, however, to the practical stresses usable on account of the physical characteristics of the belt, particularly strength and elasticity.

Wherever possible, the lower side of the belt should be made the driving side so that the sag may be at the top, which increases the arc of contact of the belt on the smaller pulley, providing the angle of the drive is not over 40 to 45 deg. from the horizontal. As the angle from the horizontal increases, an allowance must be made for the decreased pulling power of the belt by increasing the width of the belt, by allowing for the decrease in power, or by using a short-center belt drive.



Three common arrangements of belt drives.

This shows the effective arc of contact of the motor pulley and its belt under different types of service. In the arrangement at the left the small arc of contact calls for extremely high tension or an allowance of about 50 per cent in operating efficiency. Also, the weight of the belt in a long drive would cause the belt to sag and hang away from the lower pulley. The arrangement in the center is somewhat better because the weight of the belt helps it to grip the motor pulley. This, however, calls for an allowance of 15 to 25 per cent. The arrangement at the right is the best, however, but requires an allowance of about 1 per cent loss in effectiveness for every degree over 40 deg. from the horizontal. This illustration is by courtesy of Chas. A. Schieren Company.



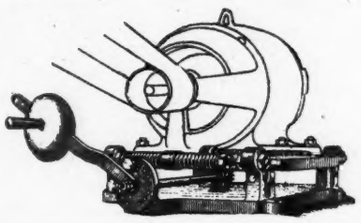
An example of a Texrope drive.

This short-center belt drive in a textile mill consists of multiple strands of a combination rubber-fabric endless V-belt operating in grooved pulleys or sheaves.

When a belt connecting two pulleys is idle, both sides or strands of the belt are under equal tension. When the driving pulley starts to turn, it increases the tension on one side or strand of the belt and correspondingly decreases the tension on the other side. The difference in these two tensions is the effective pull which transmits the torque and the rotation. In general, under operation, the tension on the tight side of the belt is about three or four times the tension on the slack side. The initial or standstill tension determines the total friction on the smaller pulley which, in turn, limits the possible effective pull. The total pull between the shafts, or the tension on the belt, is the same at all

times, both when idle and when running, and is determined by the initial tension. The transmission of load merely affects the division of the total pull between both sides of belt.

When the two pulleys are on different elevations the weight of the belt adds to the total friction on the upper pulley and subtracts from that on the lower pulley. It is inadvisable to drive vertically by long belts where the lower pulley is the smaller of the two, because excessive tension would be required to maintain a driving contact. This, in turn, increases the maintenance cost and decreases the life of the belt. The difficulties with a vertical drive may be overcome, however, with a short-center drive.



Type of motor mounting recently introduced from Europe.

This Tension Motor Base consists of a movable platform on which the motor is mounted and supported at each corner. Tension is maintained by springs and a counterweight. Horizontal springs are used for horizontal and inclined drives, and vertical springs on mountings designed for vertical drives.

The chart on this page will be found useful for determining pulley and belt data.

Single leather belts should, in general, be used for drives requiring widths up to 7 in. and for use over pulleys less than 10 in. in diameter. Double leather belts should be used for most other installations except for transmitting very large amounts of power, when three-ply belts may be used. Single belts are about 0.25 in. thick and double belts are about 0.35 in. thick. Heavy belts should not be used over pulleys of small diameter because of the sharp bend in the ply.

Rubber belts are elastic and durable, even under adverse conditions of temperature and moisture, have good tensile strength and are uniform in width and thickness; their tendency to stretch, however, is often a disadvantage. The rating of rubber and fabric-base belts is by ply or thickness and, because of the wide variety of methods of construction, the manufacturer's recommendations and ratings should be used in determining a drive.

Laced belts should not be used for motor drives; endless belts are preferable. Belts should run with and not against the lap at the joint, and the joints should be smooth to prevent jarring. The grain side of the belt should run next to the pulley because it is smoother and adheres more snugly, also because the flesh side is less likely to crack. A belt will transmit about 25 per cent more power with less slipping with the grain side next to the pulley.

Wobbling of belts is sometimes due to pulleys having unlike crowns. Other common causes of wobbling or

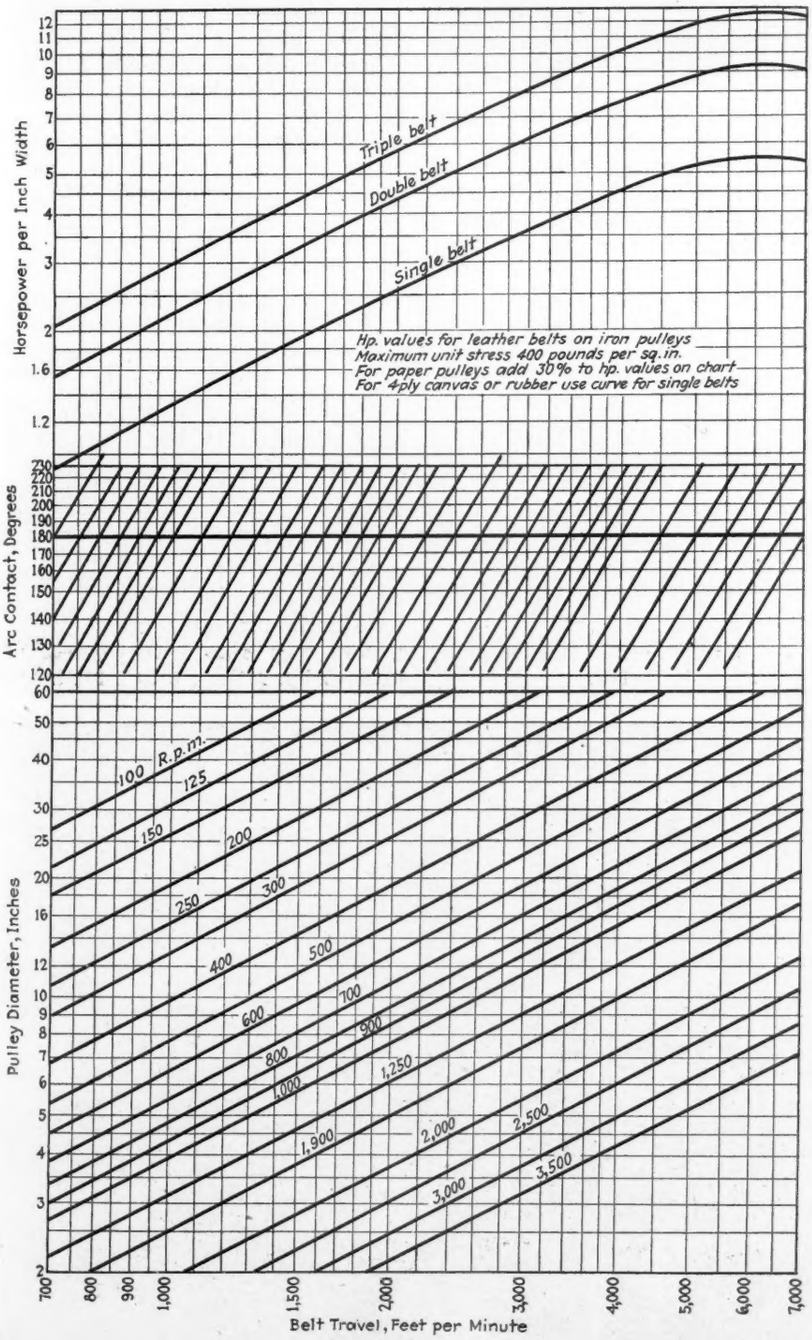
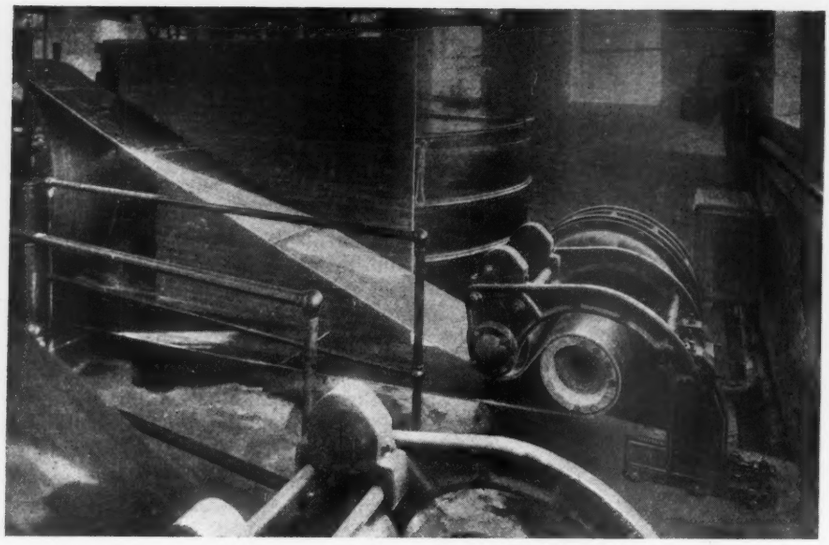


Chart for determining pulley and belt data on motor drives.

Consider that the speed of the driven machine and its pulley size are known. Find the intersection of the horizontal line, representing pulley diameter, and the diagonal, representing speed. The vertical line at this point represents belt travel. Follow this line to the diagonal of motor speed and the intersection will be on the horizontal giving the motor pulley diameter. Returning to belt travel, follow this to the horizontal line representing 180 deg. arc of contact on the smaller pulley, then proceed along the diagonal to the horizontal representing the actual arc for the case in question, which can be readily approximated. Now follow the corrected vertical to the curve for the type of smaller pulley used. The horizontal line at this point will show the horsepower per inch in width of belt which is desirable. From this the values of belt width and pulley face may be determined.



One of two 75-hp. drives in a paper mill.

Originally it was intended to use 435-r.p.m. motors on this drive. However, with the Pulmax drive connection, it was possible to use standard 575-r.p.m. motors at a saving of $190 per motor and an increase in efficiency of 1½ per cent. With special short-center attachments such as this, reduction ratios which would be impracticable on open drives are easily obtained.

weaving of a belt are neglect to make a square joint when connecting the ends of the belt, or more stretch on one edge of the belt than on the other. Flapping is usually caused by slippage between some portion of the belt and pulleys; this may be caused by grease spots in the belt. If the shafts are parallel, but the pulleys are not directly opposite, or aligned, the belt will run to one side of the larger pulley. If the pulleys are opposite, but the shafts are not parallel, the belt will run to one side of the smaller pulley.

The distance between centers of the motor and driven shafts depends upon the relative elevation of the smaller pulley and whether the driving side of the belt is on top or bottom. The distance should be such as to allow a gentle sag on the slack side when operating. Five times the diameter of the larger pulley is usually a safe center distance provided the difference between the diameter of the pulleys is not too great. The center distance has an appreciable effect on the transmitting capacity of the belt on a horizontal or an inclined drive less than 40 to 45 deg. from the horizontal because of the weight of belting suspended between the pulleys. A belt drive with comparatively long center distance, when operating under load, will have more tension on its slack side than a short-center drive. Other things being equal the tension on the slack side of the belt under load is a measure of its capacity.

The following formulas may be used for determining the length of belt required:

For open belts:

$$L = 2C + 3.14\,[(D + d) \div 2] + [(D - d)^2 \div 4C]$$

For crossed belts:

$$L = 3.14\,[(D + d) \div 2] + 2\sqrt{[(D + d) \div 2]^2 + C^2}$$

Where L = length of belt in feet (not including lap for splice).

C = Distance between shaft centers with motor on near side of sliding base.

D = Diameter larger pulley in inches.

d = Diameter smaller pulley in inches.

In determining pulley sizes the following approximate formula is generally used, in which it is assumed that the rotative speeds of the pulleys are inversely proportional to their diameters; that is, no allowance is made for loss by slip or creep:

$ND = nd;\ N = nd \div D;\ n = ND \div d$

The thickness of the belt introduces a small error in this formula. Where more exact speeds are required the following formula should be used:

$$n = N(D + t) \div (d + t):$$
$$N = n(d + t) \div (D + t)$$

Where N = r.p.m. of large pulley.

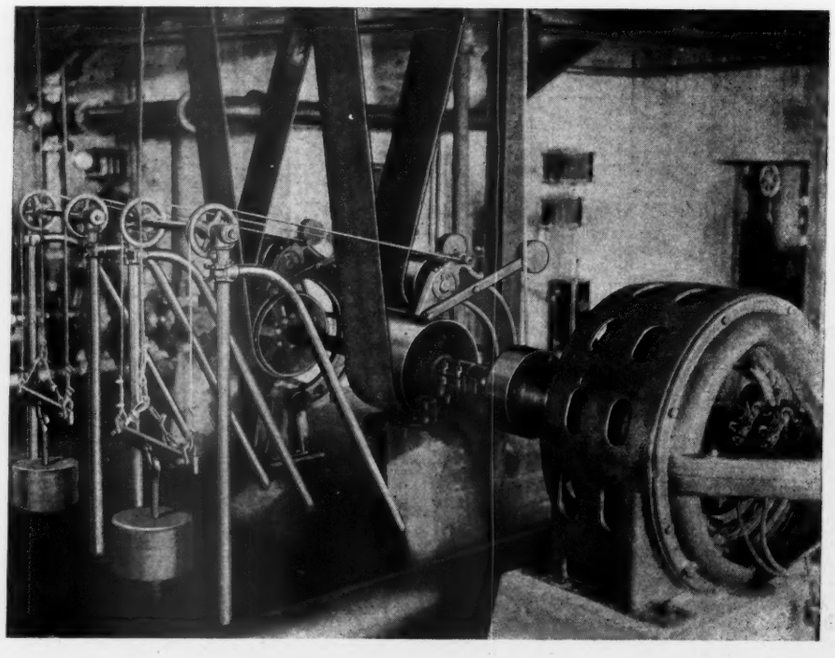
n = r.p.m. of small pulley.

D = Diameter of large pulley in inches.

d = Diameter of small pulley in inches.

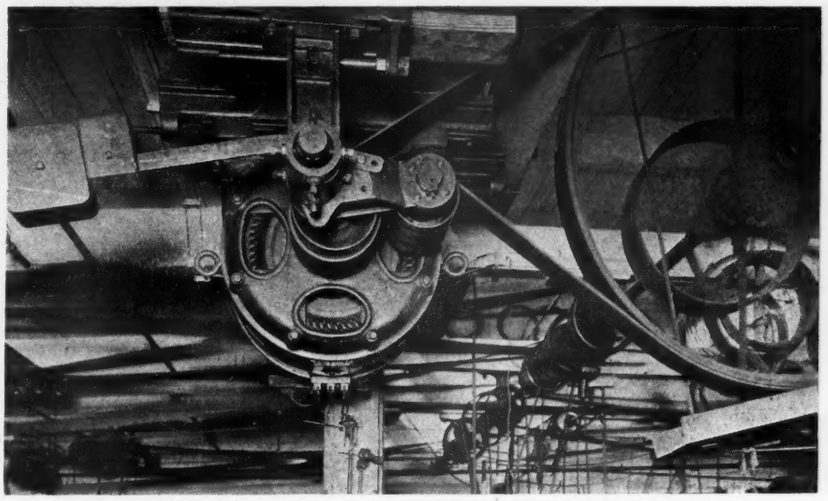
t = Thickness of belt in inches.

There is always some creep and some slippage that should be allowed for in determining pulley ratios. This is a variable quantity, ranging perhaps from 1 per cent to 15 per cent with an average value on the order of 5 per cent. The maximum advisable ratios of reduction on an open drive through a single set of pulleys are: 8 to 1 for motors of about 5 hp. rating; 6 to 1 for about



Using a vertical belt drive as a starting and stopping device.

When the Lenix drive is not in contact with the belt on this beater drive in a paper mill, the belt hangs away from the motor pulley and the beater is idle. The beater is started by the operator on the floor above, after the motor is running, by releasing the counterweights on the Lenix drive, which tightens the belt on the motor pulley.



This short-center lineshaft drive solved a serious operating problem.

Originally this was operated as an open drive on 19 ft. 3¼ in. pulley centers, with the tight side on top. This arrangement was not satisfactory because of slippage. The direction of rotation of the motor was reversed and a crossed belt was tried, which was unsatisfactory because of high maintenance cost. The belt was so tight that when the motor switch was pulled, the motor stopped dead. This Pulmax drive was installed on 4 ft. 6 in. pulley centers with the tight side again on top. It is stated that when the switch is now pulled the motor continues to turn for 1 min. and 20 sec.

10 hp.; 5 to 1 for 20 hp.; and 4 to 1 for about 50 hp.

If it is desirable to ascertain the smallest, narrowest pulley face under which the motor bearings will give service, this may be done by figuring the total belt tension required, according to the following formulas:

For iron pulleys: Tension = (3 × hp. × 33,000) ÷ belt travel in ft. per min.

For wood pulleys: Tension = (2 × hp. × 33,000) ÷ belt travel in ft. per min.

Considering the total tension as applied at the center of the pulley hub, and knowing the distance between bearings and the overhang or distance of the center of the pulley hub from the adjacent bearing, the shaft may be considered as a simple lever and the thrust on the bearing next to the pulley determined. The thrust per unit of projected bearing area may then be figured, if the bearing dimensions are known.

For motors under 50 hp. the pressure per square inch of bearing area should not exceed 70 lb. For large motors, pressures up to 100 lb. are allowable under favorable circumstances. Since belt tension must increase rapidly with a decrease in pulley diameter, motor speed remaining constant, the limitations imposed by the bearings are usually the factors determining minimum diameter and maximum face. Two-bearing motors up to about 50 hp. at 1,750 r.p.m., 100 hp. at 1,150 r.p.m., and 250 hp. at 580 r.p.m. can be used for belted service. Above this capacity a three-bearing motor should always be used.

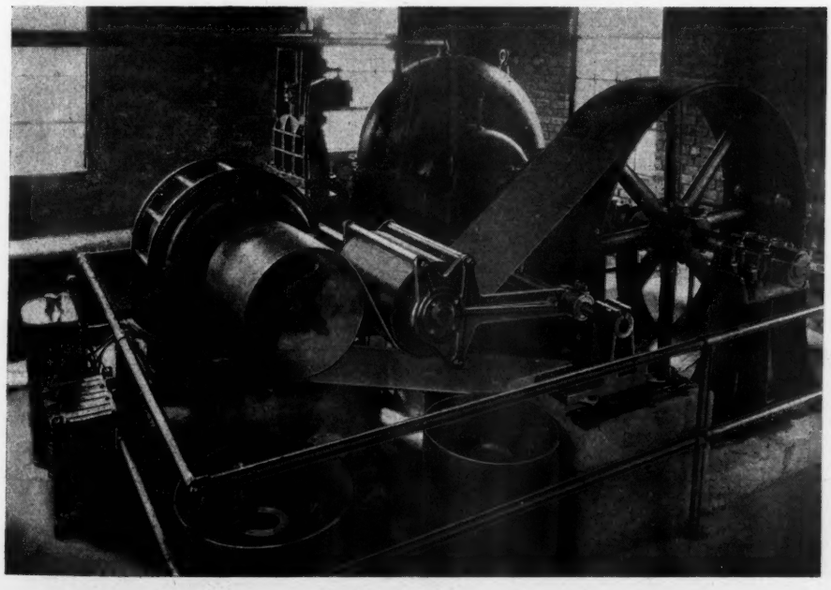
Motor manufacturers have developed a schedule of so-called "standard" pulley sizes which conform with good practice and which may well be used where they may be applied. These standard pulley sizes, with the minimum allowable diameter and corresponding face recommended, are given in pulley manufacturers' catalogs. For belts up to 12 in., the pulley face should be 1 in. wider than the belt; for larger belts, the face of the pulley should be 2 in. wider than the belt.

Large pulleys and those running at fairly high speeds should be carefully balanced by placing them on a mandrel and balancing them on ways. Where the circumferential speeds are very high, special motor pulleys should be used which are manufactured especially for high-speed service. It is well to use gib keys for pulleys (also for pinions) to facilitate removal.

Series motors should never be belted, as the belt is likely to slip off, relieving the motor of load and permitting it to race. As stated before, this characteristic of slipping off the pulley under excessive overload, which slows down the driven equipment to a low point or stops it entirely, prevents breakage in many cases. Where metallic driving links are used, such as chains or gears, some sort of safety link or breaking pin must be inserted to take care of these sudden stoppages. Drives for grinders, presses, or any reciprocating machine which may be choked require a belt or metallic safety link to protect both the motor and the machine.

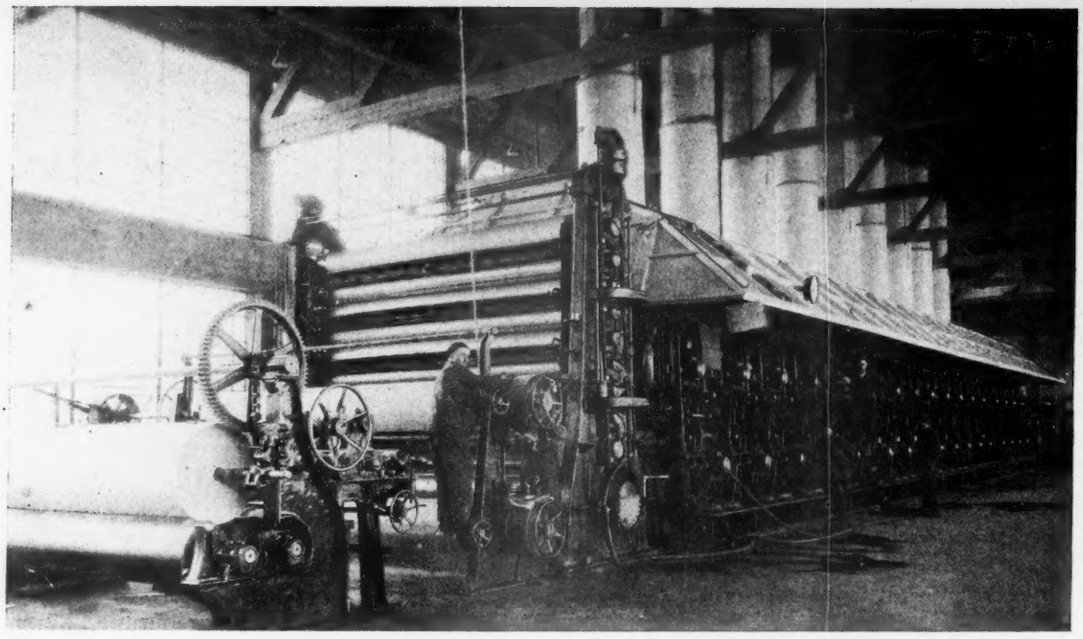
Many of the objections to belt drives may be overcome by the use of short-center belt drives. These consist of a third counterweighted pulley or gravity idler which is mounted (usually) to ride on the slack side near the smaller pulley of the drive. Screw-downs or fixed idlers are not widely used on motor drives.

(Please turn to page 128)



Obtaining different speeds from constant-speed motor drive.

Here a 200-hp., 860-r.p.m. motor drives a pump at speeds varying from 191 to 310 r.p.m. which are obtained by the use of motor pulleys 22 in. and 27 in. in diameter respectively. Only one endless belt is used. The difference in belt length due to the change in pulley diameters is taken care of by adjusting the motor and the Lenix drive on their respective slide bases.



This is a 164-in., Fourdrinier paper machine, driven by a 300-hp. motor. Push button control of complicated machines like this makes it possible to stop them at once from any one of several stations in case of accident.

Controllers for Electric Motors

By H. D. JAMES

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CONSIDERED by itself, an electric motor represents merely power that must be properly controlled and directed before it can be utilized in the most efficient manner. Hence the continual improvement of modern control equipment has enabled it to play a very important part in cutting costs and increasing the efficiency and safety of operating electrically-driven industrial equipment.

The intelligent selection and application of control equipment must, however, be based on a thorough knowledge of the designs available, the operating requirements, and the characteristics of the driving motor. This is the first article of a series in which H. D. James will discuss the characteristics and operating principles of the types of control equipment used in industrial plants.

OLDER men connected with industrial activities can well remember the time when electric drive was first being introduced, and the many questions that arose as to the value of electric drive compared with steam and compressed air. In those days even hydraulic power from a central station was considered for certain localities.

All of this is now a matter of history. Today there are very few power applications for manufacturing operations or other purposes where electric power is not used. Central stations have adopted this drive in place of steam for their auxiliary equipment. Vessels on both our inland waters and the high seas use the electric drive for their main propulsion and auxiliary equipment. Even so conservative an organization as the Navy Department has adopted the electric drive for some of its vessels.

Electrification of our steam railroads is taking place as fast as economic conditions will permit. Again, the electric motor has long been used for the pumping of oil wells. It has recently been applied for drilling these wells, making use of a new tool known as the rotary drill, and its success in this field has been definitely assured. By means of this device lower levels of oil can be commercially reached. These are but a few of the many problems that are being solved by the application of electrical energy.

Not only has the electric motor become almost the universal form of drive, but electric power is being used as a heating agent in many of our chemical and metallurgical industries. The electric smelting of steel is well established, and use of the electric oven for enameling work and in bakeries has become quite common. All of these applications require some sort of control for regulating the use of electric power, so that this branch of electrical engineering is rapidly coming to the front as one of its major activities.

It has grown from a handful of men who designed rheostats and drum controllers, until it occupies a place of equality with the other important groups in our largest electric manufacturing companies.

The comparatively rapid growth of the electric drive in industrial plants was based entirely on its economic advantages. Operating men who were familiar with other drives were reluctant to make the change. It was difficult for the older men to understand the electrical problems involved. What we might term industrial inertia operated to retard the adoption of electrical energy. This proved to be an advantage, however, for it made it necesary for the electric drive to prove its worth as it developed.

Today we find many progressive manufacturers purchasing new machines and elaborate systems of control, because they can increase the output for a given expenditure of labor and building space. It is this progressiveness on the part of American manufacturers that keeps us the leader of the world in production.

We have all acquired the "push-button habit." At home, we push a button to control our lights; the button also furnishes the power to operate the washing machine, ironing machine, vacuum cleaner and other household devices that are so rapidly taking the drudgery out of the home. In our manufacturing plants, the workman has merely to push a button to start or stop his machine. All of this convenience has been made possible by the automatic controller. The time and energy of the workman have been saved and his person guarded against accident through the ingenuity of the control designer.

When the electric drive was introduced, manual control was used, as this more closely followed the previous methods of controlling power and the mind of the engineer had not yet grasped the idea of automatic control actuated by small master switches or push buttons. Manual control is still used today, and has a real place in the art, but the tendency is strongly towards remote control with automatic features.

In a modern steel mill two operators, who sit in a "pulpit" overlooking the mill, use both their feet and hands to operate master switches which, through the agency of remote control, co-ordinate the speed and direction of the large mill motor and of all of the auxiliary motors, so that the steel billet is passed back and forth between the rolls with almost human intelligence.

Automatic control has made it possible for one person to do the same work that formerly would have required several persons, and to do this work with greater efficiency and safety. It has placed the operator remote from personal danger; so, in case of an accident, he can exercise clear, cool judgment in doing the correct thing promptly.

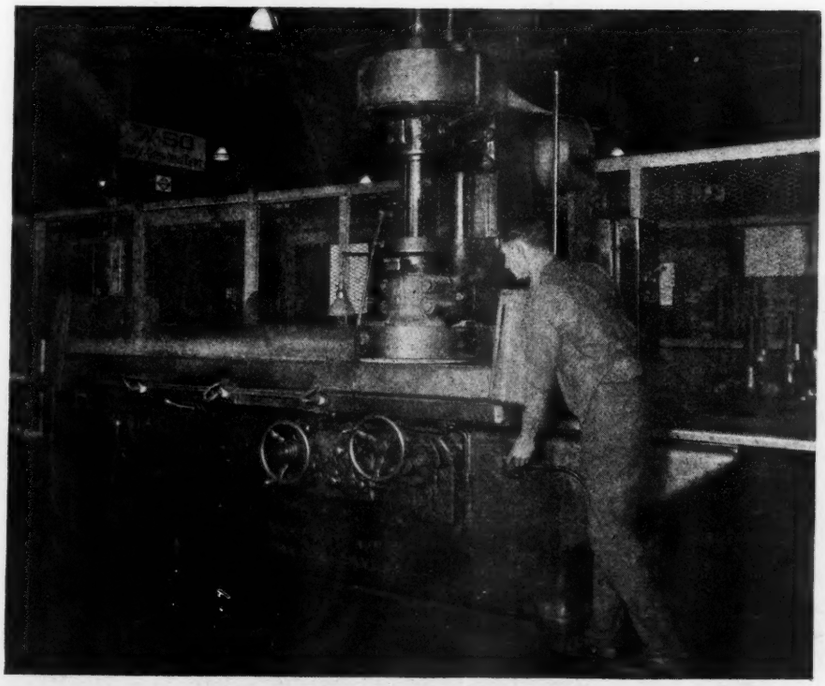
Many of us remember how a workman was formerly required to shift the belt by hand when he wished to change the speed of his machine; in many cases the workman was required to reach across the moving parts of the machine in order to operate the control lever. If, through accident, some portion of his clothing or one of his hands was caught in the machinery, it was almost impossible for him to stop the machine in time to avoid serious injury.

The modern control system provides master switches in convenient places, so that there is little or no danger to the operator in starting or stopping the machine, or changing its speed. Where the process introduces personal hazards, such as are present around rubber mills, paper calenders, printing presses, and other processes in which the workman must place his hands near rolls, the control system provides emergency switches so located that, in the event of accident, the workman can easily stop the machine.

Where larger motors are used and it is necessary to supply a considerable amount of electric power, automatic control permits both the controller and motor to be placed remote from the operator, so that any accident to this equipment will not endanger the workman. The controller can be enclosed or protected if within reach of the workman, to prevent him coming into accidental contact with live parts. This question of safety to persons has been given much careful study by control engineers and means have been provided to protect not only the legitimate operator, but also the curious investigator.

In many cases, the sequence of operation plays an important part in an operation or process. Frequently, the substitution of a mechanical sequence is an improvement over manual operation. The operation of a mine hoist may be taken as an example. As the car approaches the landing, it is necessary to slow down the hoist engine in order to make a safe stop. If the slowing down is initiated by the operator, he will try to be on the safe side and will reduce the speed a little ahead of the time required for making the stop.

If a mechanical device is used, it can be set to initiate the slowdown



Modern control equipment has greatly increased the safety and ease of operating machine tools. This is a 22-in. surface grinder that is controlled by a push button which can be seen under the left hand of the operator.

when the car is nearer the landing, as it is always operated at the same point. This results in giving the car a greater average speed so that it can make more trips per hour. On one particular application, it was reported that the introduction of an automatic slowdown and stop mechanism increased the number of trips made by the hoist about 20 per cent. If this is true, it is an unusual case, but indicates that considerable improvement may be expected.

Again, many processes require a definite sequence of operation. This can be obtained by interlocking the various controllers so that each performs its function after the previous one has completed its cycle. The function may be automatic or the interlocking may be used only to prevent wrong operation. Thus, in a coal-handling plant, the coal is lifted by a conveyor to a hopper and then passed down over screens and conveyors into different bins. The machinery at the delivery end of the plant is started first and care is taken to see that coal is not fed into machines that are not running. If one section of the machine is stopped, it is necessary to stop automatically the rest of the machinery feeding coal up to that point; otherwise there would be an accumulation of coal at the blocked section that might cause loss or damage. Interlocking features for a plant of this kind are relatively simple and easy to obtain.

An ash hoist that operates automatically through a complete cycle requires a more complicated control. The ashes are dumped into the car, or skip, which then automatically starts up an incline; as it approaches the upper limit of travel, it is slowed down and stopped at the point where the skip empties its contents into a conveyor. After a short interval of time, the motor is started in the reverse direction, returning the skip to its initial position where it is stopped for a given interval while it receives a new charge of ashes. The cycle is then repeated, either by an automatic timing device starting the skip, or by an operator pushing a button.

The car dumper is another illustration of interlocking controllers. The car is first hauled from a siding up to the cradle, where it is clamped in place and hoisted the desired distance. The cradle is then rotated, emptying the contents of the car on an apron where it passes through a chute to a car or vessel. Following this the cradle is returned to its starting place; the car is released, and the mechanical device pushes the car out of the way, so that the cradle is ready to receive the next car.

Many applications will occur to the readers, where the automatic interlocking of control will give the necessary performance, insure safety of operation and, in some cases, provide for automatic sequence.

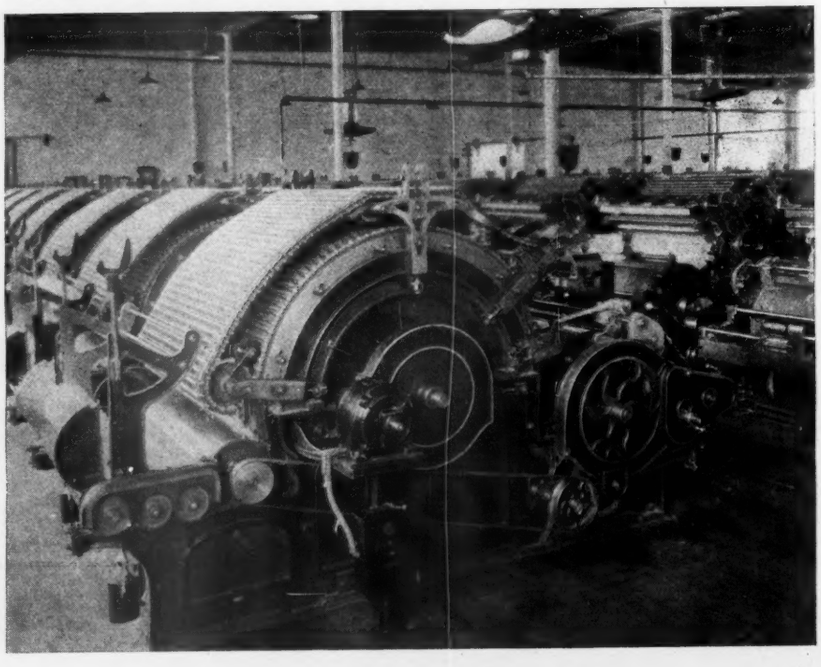
Before we are ready to consider the control, however, we must select the type of motor most suitable for the drive under consideration. This selection will be limited by the source of power available. If alternating current is employed we are limited to a squirrel-cage motor that operates at certain fixed speeds, or to a motor whose speed can be changed by the use of external resistances, the values of which depend upon the load on the motor. This type of motor is known as a varying-speed motor, in distinction to a motor whose speed remains substantially the same at any load.

There are types of control for a.c. motors that permit of speed adjustment over a wide range, but such motors and control are complicated and are not used except in large sizes. Types of adjustable-speed a.c. motors have been used in limited number, but need not be considered for ordinary applications. If the nature of the load requires an adjustable-speed motor, a source of d.c. power should be available. Some manufacturing establishments convert all of their power from alternating to direct current, as the latter is a better source of power for their particular applications.

The squirrel-cage induction motor is the one most commonly used where constant speed is required. This motor can be wound to give several different speeds by changing the number of poles, but this is feasible on only very few applications. In general, we can assume that a single-speed motor is used. The control for this motor may connect it directly to line voltage, or a means of reducing the starting voltage may be provided. This latter type of control is usually supplied with the larger motors.

The wound-secondary motor is not used so much as is the squirrel-cage type. It is usually applied to cranes, pumps, fans, air compressors, and the like, where operation at different speeds is desired. If the load remains constant, the speed adjustments are satisfactory. The controller provides a means for opening and closing the power connection to the primary of the motor and means for inserting external resistance in the secondary circuit for starting or speed regulation.

Direct-current motors are used for a great variety of applications, although the total number of such motors in use is much less than in the case of the a.c. squirrel-cage type. This variety of applications presents some of the most interesting problems in control design. Direct-cur-



These carding machines are individually driven by small motors, which are controlled from the push-button station shown in the foreground.

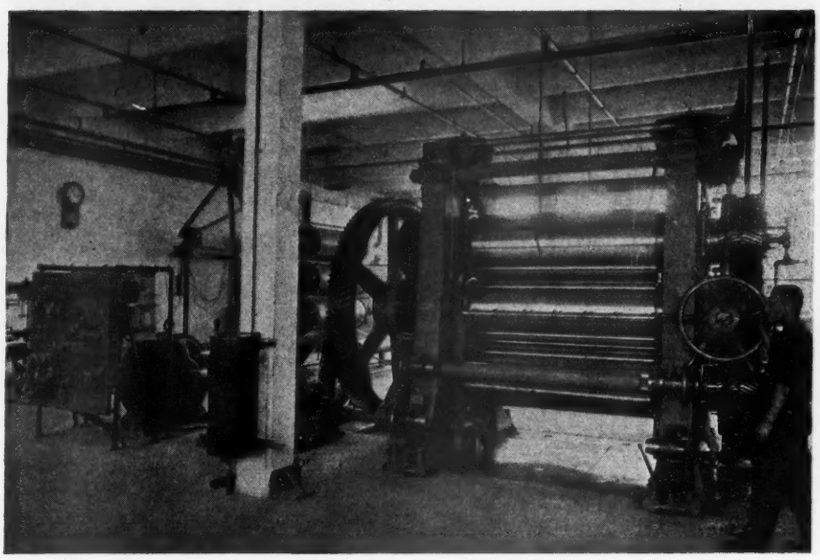
rent motors are available with shunt, series or compound windings on their field. Each type has its particular characteristics, so that it is important to select the correct type for the particular application. The types of control used with these motors are too numerous to be summarized here, but will be dealt with later.

After the most desirable type of motor has been selected, modifications of its characteristics can be studied for a special application. For example, the squirrel-cage induction motor, which is the simplest type of motor in commercial use, has a considerable range of characteristics largely dependent upon the design of its secondary. The general-purpose, stock motor of this type is intended to operate at constant speed and is usually not applied where the machinery is stopped and started very frequently. This motor has a relatively low-resistance, squirrel-cage winding, and takes about six times full-load current if started at full voltage. The larger sizes of motors are, therefore, provided with reduced voltage starters in order to limit the demand on the power system when starting.

This same type of motor can be provided with a high-resistance secondary which gives it much better starting characteristics, although these are obtained at the sacrifice of its speed regulation and its efficiency when operating at full speed. One of the best illustrations of an application using this type of motor is the electric elevator. This service requires the motor to be stopped and started frequently, but it runs for only short periods of time and, therefore, a high, full-load efficiency is not essential.

In designing the motor for this application, it is necessary to give careful attention to the mechanical details. In operating an elevator, mechanical energy is stored in the rotor of the motor during the acceleration period. When the elevator is stopped, this mechanical energy must be absorbed by the mechanical brake. Therefore, a motor having a small-diameter rotor will be much more satisfactory than the standard design. An elevator motor has a relatively long rotor of small diameter.

The continual starting and stopping of the motor first in one direction of rotation and then in the other introduces mechanical stresses that require a rigid construction with well-braced windings. The successful use of squirrel-cage motors for elevators is largely due to the very excellent special designs that have been made available for elevator service.



The 75-hp., double-voltage d.c. motor driving this rubber calender is controlled by the magnetic controller shown at the left.

Laundry machines present another interesting problem. These machines are operated for a few revolutions in one direction, and are then operated in the reverse direction for an equal number of revolutions. The cylinder carrying the wash has considerable inertia and it is, therefore, necesary to limit the torque of the motor at the instant of reversing. On the other hand, considerable torque is required to start the machine from rest. Earlier types of control for these machines made use of a voltage-reducing device, such as a resistor, that was connected in the primary circuit of the motor at the time of reversing, to limit the torque. This method made the control more complicated and increased the cost of the equipment.

A better solution was found in designing the motor so that the torque at reversal is less than the starting torque, which eliminated the resistor and simplified the control. This improvement illustrates what can be accomplished by a careful study of the application.

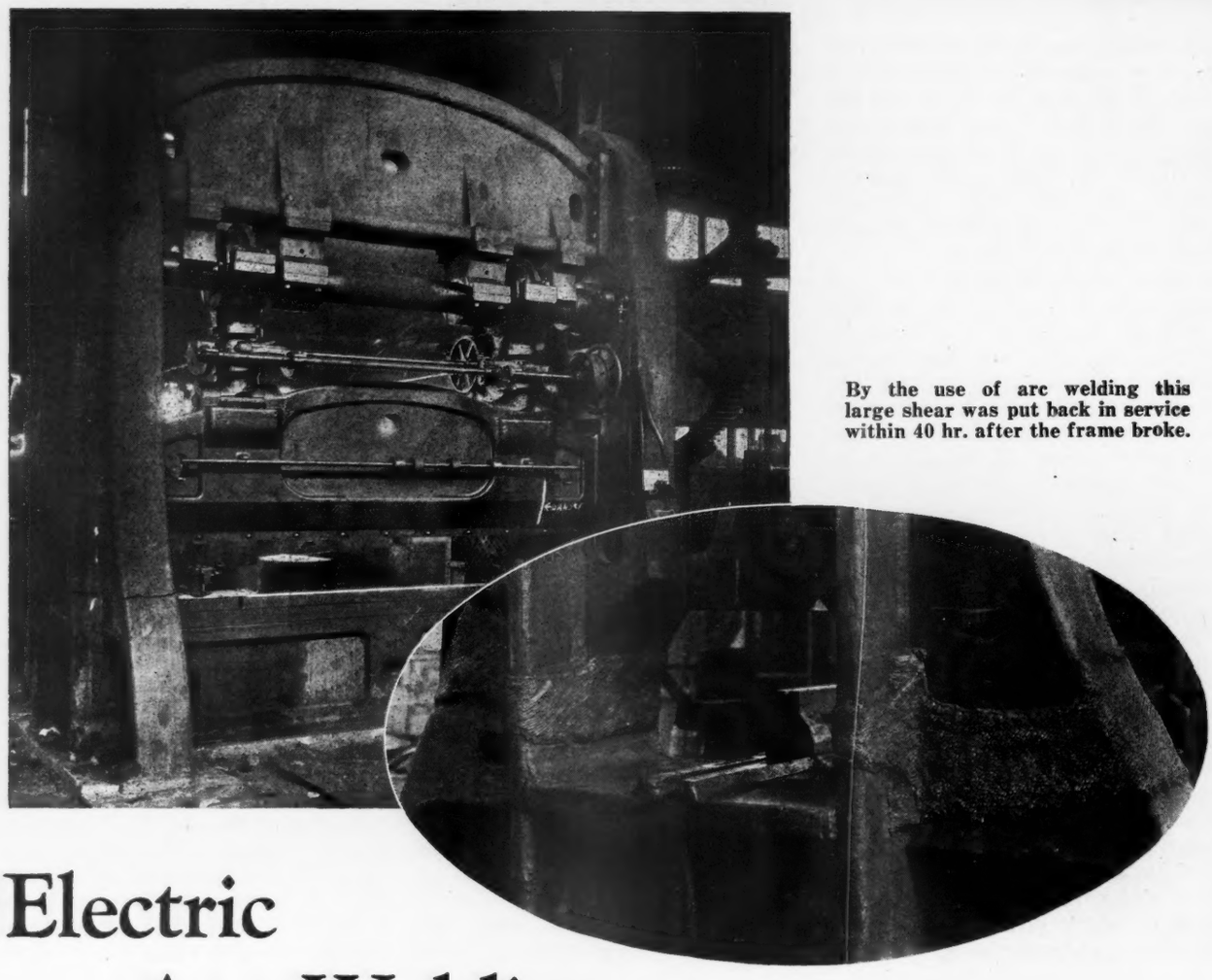
When the reversing motor was first applied to planers, a satisfactory system of control was developed, but the application as a whole was not successful because the proper type of motor was not available, and the machine tool builders attempted to couple the motor that seemed best suited to the service to the existing design of planers. A careful study of the motor and control requirements, as well as the design of the planer, has resulted in such marked improvements that the belt-driven planer is largely a thing of the past.

These illustrations are given to show that a successful electric drive may require the co-operation of the machine builder, as well as the electrical designer. Many times the control can be simplified by selecting a motor that has characteristics particularly adapted to the drive. It is the function of the controller to furnish the characteristics that cannot be conveniently incorporated in the motor; therefore, a careful balance should be struck between the motor and control designs to obtain the simplest and most rugged equipment.

By itself, a motor represents uncontrolled power. It must be directed, so to speak, so that the mechanical energy it supplies can be made to do useful work in a prescribed manner. Again, a motor cannot protect itself against overloads, or damage to itself and the driven equipment through operation under improper conditions.

Therefore, in addition to its prime function of properly starting, stopping and, if necessary, reversing a motor, the control may be required to furnish protection against overload, phase failure or reversal, accidental starting on restoration of power after failure, or to provide for restarting after power failure, and perform other functions that are necessary.

The next article of this series will appear in an early issue and will discuss the salient features of the different types of control in industrial use.



By the use of arc welding this large shear was put back in service within 40 hr. after the frame broke.

Electric Arc Welding

in Maintenance Work

By ROBERT E. KINKEAD

Chief Engineer, Welder Division, The Lincoln Electric Company, Cleveland, Ohio.

MANY maintenance men have had the experience of seeing carefully planned economies wiped out and maintenance costs go skyrocketing because of unexpected breakdown of essential equipment. The use of electric arc welding has grown rapidly in maintenance work because in many cases it has enabled production delays and repair costs to be greatly minimized. In some plants, the arc welder is regarded in about the same light as a sprinkler system; in fact fire loss can be covered by insurance, which is not the case with sudden failure of equipment.

An accident at the Armour Grain Co.'s elevator at Chicago illustrates very well the value of arc welding in emergencies. The trouble occurred in the autumn three years ago. As is usually the case, this was the time when the elevator was the busiest. Grain was coming from the West as fast as the railroads could bring it. The elevator was working night and day loading ships for Eastern ports and conveying the grain to storage bins.

Right at the peak of this activity, a careless switching crew backed a string of cars through the thin wall of the elevator into the 1,000-hp. Corliss engine driving the conveying machinery. Backing a freight train into a Corliss engine with a 20-ton flywheel going at full speed is, as was shown by this experience, likely to create a good deal of havoc.

A serious situation was brought about, as that elevator had to take the grain from the cars as they arrived, or stand a heavy demurrage loss on both cars and ships. Electric arc welding saved the day. The accident occurred at 7 p.m. on Sunday, and the welding crew started picking up pieces of the bell cranks and putting them in a basket at 9 o'clock the same evening. At 9 o'clock Wednesday morning, the elevator was again operating at full speed.

A 36-in. break in the frame of the engine had been welded, and the bell cranks all put together and welded without the necessity of even remachining them. The connecting

rod and valve rods were straightened, and a weld was made in the outboard bearing pedestal.

No attempt was made to repair the fly-wheel. There was sufficient friction load on the engine to make it entirely safe to operate it, with a man constantly at the throttle.

The welding job was done by The Mitchell Co., a firm of emergency master mechanics that uses welding as a matter of course to save time. This particular firm sends its crews of experts into a plant in distress with the same speed and discipline that are displayed by a well-trained fire department. The crew, under a captain who is an all-around engineer, comes in, takes command of the part of the plant that is crippled and remains in full charge until operation is resumed. Arc welding equipment on motor trucks is called out by telephone as required. Practically all types of equipment are mounted on motor trucks so that it can be brought to the scene of the accident in a matter of minutes.

One important advantage of arc welding is that it permits the repair of heavy gray-iron castings without the necessity of dismantling or preheating. A long time is required to repair heavy shear frames like the one shown in the headpiece at the beginning of this article, if they have to be taken outside the plant and preheated. It took a well-trained crew of arc welding operators 40 hr., working in 8-hr. shifts, to repair the break in the frame of this shear.

Large plants in which heavy production schedules are maintained, find that arc welding equipment is a good investment, that may be considered in the same class as insurance. The Timken Roller Bearing Co.'s plant at Canton, Ohio, is a good example of an organization that protects itself against preventable loss by the use of arc welding.

Pinion seats on rolling mill shafts are built up in the Timken plant at about one-fourth of the cost of new shafts.

Furthermore, machinery that breaks or wears out before its time requires capital expenditure for replacement. By getting longer life out of machinery and equipment, substantial economies are made by the Timken Roller Bearing Co., to name only one example. More spectacular management economies have been effected than those accomplished by extending the useful life of expensive metalworking machinery, but from the stockholders' point of view careful conservation of capital invested in machinery is evidence of intelligent management.

In this plant, the machinery and equipment used in the manufacture of the product are, in many cases, built especially for the purpose. Failure of this machinery by breakage or through wear was formerly the cause of serious and costly delays in the production schedules. Special machinery parts take a long time to obtain and are very expensive when they do arrive. Timken maintenance engineers have provided a well-equipped welding department for quick repairs and can now have broken and worn parts welded within a few hours. Both arc welding equipment and gas welding torches are available in the welding department, in which highly-trained operators are employed.

A rather striking example of the economies effected in this plant by emergency welding repairs occurred recently in connection with a repair job on a 50-ton draw bench. Tension is applied by a massive chain that passes over a sprocket on a shaft, which in turn is driven through a set of gears by a 100-hp. electric motor. The drawing head is used to size heavy tubing, preparatory to cutting it up into sections from which the outer roller bearing races are made.

The sprocket had become badly worn before it was accidentally discovered. It was seen that failure of the sprocket might occur at any moment, which would put the draw bench completely out of service. This, in turn, would cause serious disruption of production schedules in several departments.

To replace the sprocket would have taken 10 to 15 days, if it were ordered from the manufacturer, or 4 to 5 days if it were rushed through the tool room. It was estimated that to dismantle the 12-in. shaft carrying the sprocket, press the old sprocket off and the new one on, and reassemble the machine, would take about 36 hr., at a labor cost of about $300. The cost of a new sprocket was estimated to be about $150.

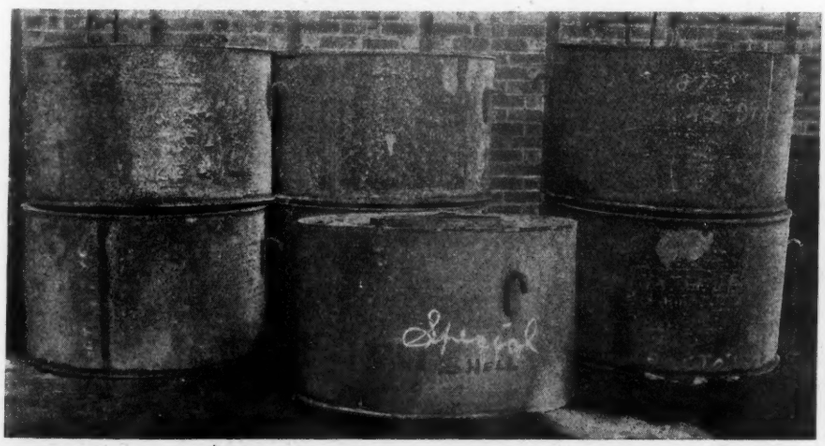
It was eventually decided to remove the chain and build up the teeth on the worn sprocket by electric arc welding. This did away with the necessity of even taking the shaft out of its bearings. After welding was completed, which required 8 hr., the teeth were ground out with a portable grinder to conform to a templet.

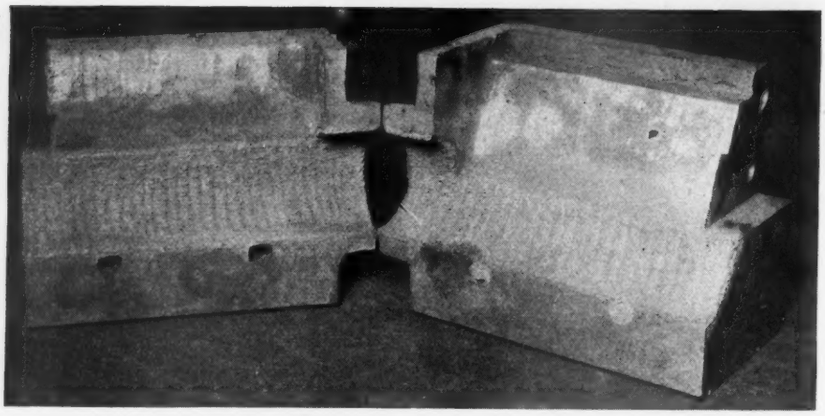
The cost of building up the teeth by welding, including grinding to size afterward, amounted to about $20. Replacing the sprocket would have cost about $450.

The engineers in this plant point out that a broken casting loses its value, not because the material in it is worth any less than before it was

These annealing boxes are made and maintained by the use of arc welding.

By welding cracks and air leaks as soon as they appear, these boxes can be made to give two or three times the length of service that would ordinarily be obtained.





It is a simple matter to compensate for wear on this magazine for a scrap press by adding new metal with the electric arc.

This is a good example of equipment failure due to the wearing away of less than 0.5 per cent of the original weight. Arc welding makes it possible to save the original investment at comparatively low cost.

broken, but because it has no utility as a machine part. As soon as the parts are welded together again, the utility is entirely restored, as there has been no loss in the value of the material.

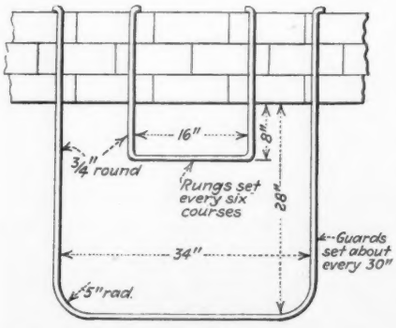
Another engineering viewpoint which has become an established policy of Timken management is illustrated in the handling of worn pieces of machinery or equipment. As a general rule, failure of equipment by wear is caused by disappearance of less than 0.5 per cent of the weight of the worn piece. With conservation of initial capital outlay in mind, it is obvious why the plant engineers are more interested in replacing the small amount of missing metal, rather than in replacing the whole part.

The great saving in time made by the use of electric welding in the operation of railroads and steamships is pretty widely known. Practically every engine house on the important railroads of the country is equipped with arc welding apparatus. Broken locomotive frames and leaking boilers are repaired in a remarkably short time. It has been said that nearly 50 per cent more locomotives would be required on the railroads of this country, if it were not for the speed with which repairs can be made with arc welding.

In conversation, several maintenance men have expressed the same opinion about the advantage of being equipped to handle emergencies with arc welding. One well-known Detroit maintenance engineer said that the "Old Man" never seemed to know he had a maintenance department until something happened to shut down an important section of the plant. In the old days before arc welding, the maintenance department was never in evidence except in some emergencies when the men could not do much to speed things up. With good arc welding equipment and with high-class operators the story is entirely different—when a breakdown occurs, the maintenance crew is on the job with the "electric needle" ready to sew up the broken parts.

Construction of Rungs and Safety Ring for Ladder on Brick Wall

IT IS common practice to erect a steel ladder on the outside of a brick wall where the height is considerable, and to put safety rings outside the steps so that a man may rest or be guarded against falling backwards in case he should slip. The strain of climbing a vertical wall is considerable and even if a man is not carrying a load he may wish to rest occasionally. Where these walls are built by specialists they usually have stock parts for constructing the ladders and rings. However, where the local Building or Maintenance Department has this work to do, such parts are not always available.



Steel rungs in ladder and safety guards which were placed on 40-ft. brick wall.

It is not necessary for the ends of the steel sections to extend entirely through the brick wall, but they should be set in at least through the second tier of brick.

The accompanying drawing shows clearly the construction of a safety ladder that was erected on the outside of a 40-ft. wall of a building into which refuse was to be exhausted. This inexpensive construction fortunately represents good practice, also.

Both the rungs and the safety rings are made from ¾-in. round stock. These pieces were cut off cold on the anvil and the ends were given a blow with a heavy hammer to put a bend at the end, as shown. This bend was of no definite amount but merely to add to the burr from the cutting off so as to make a knob that could not be pulled through the brick work.

The bend was made on a Wallace bender. The rungs or steps were given a bend of short radius. The safety rings were given a bend with a 5-in. radius, which was easy to make and which permits of ample climbing clearance. The round corners also improve the appearance. Some stack safeties are made with round or hoop rings, but these seem to restrict climbing space and interfere with a man carrying anything strapped on his back. However, it is safer to pull any tools or materials up with a rope than to try to carry them up.

When this structure was being built up, the steel parts were laid in between the joints in the brick as the courses were laid. The rungs were placed between every six courses of brick, which were approximately 15 in. apart, an easy climbing distance. The safety rings were placed 30 in. apart because it is not necessary to have them as close as the rungs.

In laying the bricks, care was taken to see that each steel bar was pressed into a bed of cement mortar and that the joint was well filled around the steel. This insured a firm grip between the steel parts, to resist any tendency to pull them directly outward. In addition, the crook at the inner end of each leg gives added security against any tendency of the rungs or guards to loosen or pull out.

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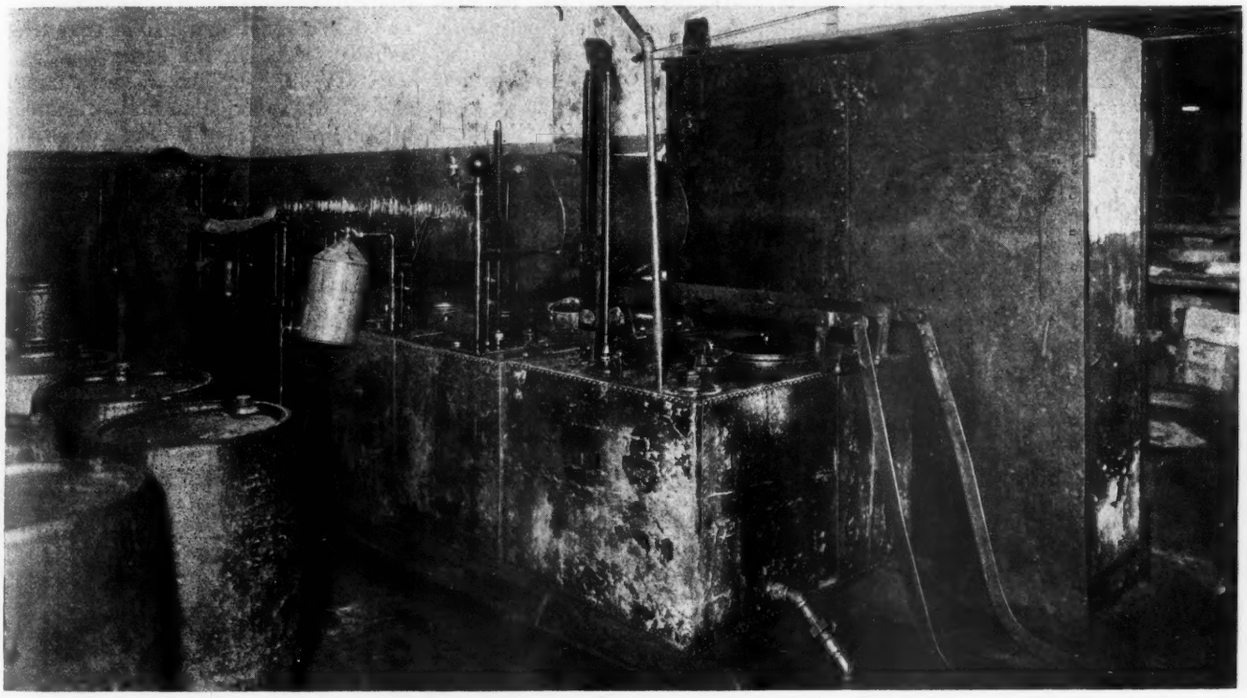
Methods of Storing and Handling Oil and Grease Lubricants

in Industrial Plants

By FRANK E. GOODING
Associate Editor, Industrial Engineer



Oil tank storage system in use at the Automatic Electric Company, Chicago, Ill.

In this battery of ten Bowser oil tanks, eight are of 120-gal. capacity, one 160-gal. capacity and another 230-gal. Lubricating oil, paint oils and other oils or liquids used in the plant are stored here and issued on requisition to the various departments that make use of them.

PREVIOUS articles that have appeared in this series on lubrication have discussed lubricants, their selection, devices for their application, and their use on some of the more common types of equipment. Even after all of these problems are solved there is still the necessity of providing adequate and proper storage and handling facilities. These do not always receive the attention they merit.

There are three main reasons for providing special equipment for the storage of lubricating oils—namely, prevention of loss and waste, fire hazard, and provision for measuring as issued on requisition. Although the fire hazard and loss from seepage are not as great now with the use of steel instead of wooden containers for shipping the oil, nevertheless, these two factors alone are of sufficient importance to make the cost of special storage and measuring equipment a good investment and frequently repay the cost within a period of a year or two, under ordinary conditions.

Many plant executives believe that they are saving this cost by attaching a spigot or faucet and using for storage the steel drums or casks in which the oil is received. In such a case the drums are usually laid on their side and the oil drawn out through the faucet as needed. Special pumps are sometimes used with the drums standing on end. There are several objections to this that are not fully appreciated by many plant executives. First, faucets often leak and some form of container or sawdust must always be provided to catch any drippings, which are practically a total loss.

The oil-soaked sawdust and the open oil form an important fire hazard that is always taken into consideration by the fire inspector when making his inspection upon which the insurance rate is based. Paints and several other oils and liquids that are also used in many industrial plants offer a much greater fire hazard and correspondingly affect the insurance risk to a greater extent. Storage arrangement for these liquids is frequently provided in connection with lubricating oils. However, the lubricating oil is one element of the risk and in case of fire has a special hazard, as is explained later.

Lubricating oil in containers offers very little fire hazard in itself, because it gives off practically no volatile or inflammable vapors until it is heated to or above its flash point,

which is considerably above ordinary room temperature but would be the condition in case of a fire surrounding the oil container. However, open oil will add fuel to the flame if the room should become on fire. Oil-soaked sawdust is highly hazardous.

Lubricating oil, if released in quantities in a fire, throws off heavy, suffocating fumes that force the firemen out of the building and so increases the difficulty of fighting the fire. For example, a recent fire in a Mid-Western industrial plant was almost under control until the heat burst open or melted the faucets on two drums of lubricating oil. In this fire one man lost his life due to the fumes and the firemen were forced so far from the source of the flames that the plant was practically a total loss.

It is stated that the special lubricating oil tanks, such as are manufactured by several concerns and are shown in some of the accompanying illustrations and described in more detail later, are provided with vents that permit the vapors to escape more slowly, in case the fire surrounds the tank, and to burn without causing heavy fumes such as result when the oil floods the room when a cask or drum is burst open.

Comparatively few plant executives have any real appreciation of the amount of loss through leakage. The amount of oil from even a faucet that is dripping slowly, either because of a leak or because it has not been shut off completely, will be considerable in a comparatively short time, as is shown in the accompanying combination chart and table on page 110. For example, a leak of only one drop per second would amount to 1½ gal. in 24 hr. Many times even more heavy dripping from partly closed faucets goes on undisturbed over night and often over the week end as well. Usually the first man to find the wasted oil cleans it up as well and and as quickly as he can and the management never learns why the drum was used up so quickly.

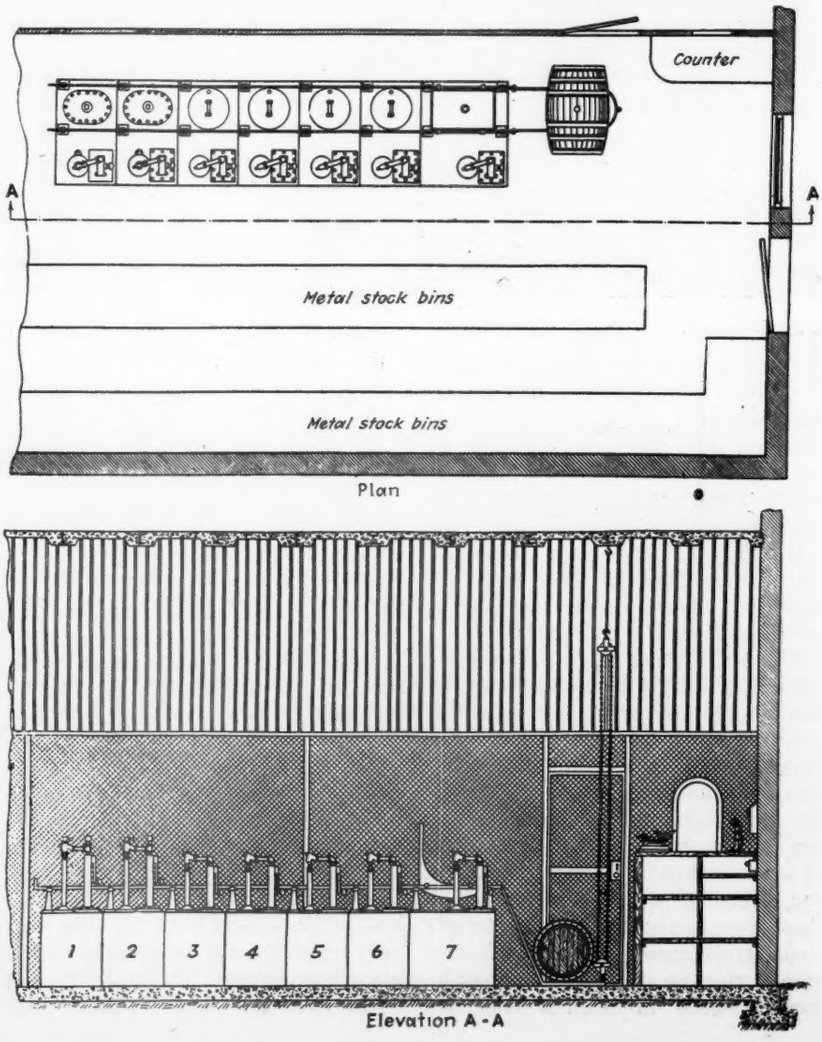
The representative of an oil company stated that it was not at all uncommon to find from ½ gal. to 5 gal. of oil remaining in the barrels when they are returned to the oil company. The drums are always emptied and cleaned before being used again, and so this oil remaining in them is a total loss. However, it has been paid for and this extra expense adds to the cost of lubrication in the plant.

Probably one of the most extensive and expensive practices in oil storage is to leave the oil and other liquid storage rooms open on a "help-yourself" basis. This is true whether the oils are stored in the original containers or in special tanks. When any material is left open in the storeroom for general consumption whenever the different men or departments in the plant want it, there is always a tendency to belittle its value, because men are not inclined to be careful with material which they do not consider as having much value or upon which the management does not put its real value. Also, there is an inclination to take as much as they can at a time, and if they do not have any proper place or container in which to keep the surplus lubricant, it is likely to be lost or to get dirty. In either case it is wasted. However, if the dirty oil is used, it may cause bearing trouble. Comparatively few industries have a dust-free atmosphere, where open oil would not become contaminated within a short time so that its use in bearings might be disastrous.

In plants where the oil storage is open to anyone in the shop the men are likely to congregate when going after the oil. When the oil is drawn through a faucet, they may not watch it close enough and so overfill the container and add to the loss and waste. If men come in by themselves, there is a danger that they may try to "steal" a smoke while waiting. This adds to the hazard because of sawdust as well as the other and more inflammable oils that are usually stored in the same location.

Heavy oils run very slowly during the winter, particularly in unheated oil houses. When a man comes in to get oil and knows that he will have to wait for some time while his measure is filling, he is likely to visit in a neighboring department where it is warmer. It frequently happens that he either forgets the oil entirely or else does not time his visit properly and upon his return finds that the measure has overflowed. A

A common method of arrangement of oil storage in the stock room.



shovelful of sawdust will quickly cover up the mistake.

Another disadvantage of using the drums or casks as containers is that it is rather difficult to know how much oil is left in them. If the quantity on hand is not known or is not quickly ascertainable, there is great likelihood of running out of a supply of oil.

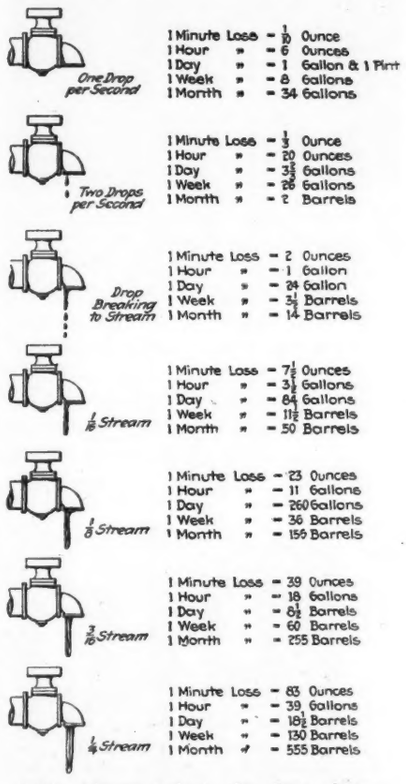
Many industrial concerns that have investigated their oil-storage problem and evaluated the wastes have discovered that poor methods of handling are expensive. A number of types of storage equipment are on the market and also different methods of storage are used to serve particular purposes and meet special conditions. The various types of equipment available are, in general, quite similar. In practically all cases they consist of a square or rectangular steel tank, with riveted and soldered or welded joints. A type of tank that will hold 2 bbl. of lubricant will occupy little more floor space than a barrel; with some types of equipment the width of the tank is less than the diameter of the barrel. This gives a space-saving advantage, as well as an increased storage capacity, which is especially valuable where space is at a premium.

With adequate storage tanks the casks or drums can be emptied practically as soon as they are received and the empty containers returned at once, so that the plant does not have to give them storage. This is an advantage, however, of which comparatively few concerns make full use, with the result that in many cases the empty containers are retained indefinitely and occupy considerable valuable space. A number of empty barrels standing around does not improve plant housekeeping.

Practically all of these storage tanks are provided with a measured discharge whereby each turn of the crank delivers a definite amount of oil. The quantities delivered vary somewhat with the different tanks. The particular advantage of the measuring feature of these storage tanks is that when oil is issued on requisition a more careful check can be made of the quantities given to each individual.

Many plants that have a carefully worked out requisition system for practically all other materials issued from stock have, for some reason or other, not placed the oils, either those used for lubricating purposes or other liquids used in plant production or processes, under anywhere near as careful checking system. This is attributed to some extent to the belief that the oil cannot be used anywhere else than in the plant.

The ordinary oil containers used around the shop are not very accurate in their rated measurements and if filled for 1 gal. or 5 gal., whatever they are supposed to hold, the actual amount may be either considerably over or under. The only way to check on this is to measure the liquid as it is taken from the tank. With a requisition routine, an assurance that the proper quantities that are called for are issued, and a cost system, it is always possible to know how much lubricants actually cost, and no industrial activity can be controlled unless its costs are known and analyzed. Where this is done, it is possible to compare the value of different lubricants and base the decision as to which is the best on actual facts instead of on a guess.


One Drop per Second
1 Minute Loss = 1/10 Ounce
1 Hour " = 6 Ounces
1 Day " = 1 Gallon & 1 Pint
1 Week " = 8 Gallons
1 Month " = 34 Gallons
Two Drops per Second
1 Minute Loss = 1/3 Ounce
1 Hour " = 20 Ounces
1 Day " = 3 2/3 Gallons
1 Week " = 26 Gallons
1 Month " = 2 Barrels
Drop Breaking to Stream
1 Minute Loss = 2 Ounces
1 Hour " = 1 Gallon
1 Day " = 24 Gallon
1 Week " = 3 1/2 Barrels
1 Month " = 14 Barrels
1/16 Stream
1 Minute Loss = 7 1/2 Ounces
1 Hour " = 3 1/2 Gallons
1 Day " = 84 Gallons
1 Week " = 11 1/2 Barrels
1 Month " = 50 Barrels
1/8 Stream
1 Minute Loss = 23 Ounces
1 Hour " = 11 Gallons
1 Day " = 260 Gallons
1 Week " = 36 Barrels
1 Month " = 156 Barrels
3/16 Stream
1 Minute Loss = 39 Ounces
1 Hour " = 18 Gallons
1 Day " = 8 1/2 Barrels
1 Week " = 60 Barrels
1 Month " = 255 Barrels
1/4 Stream
1 Minute Loss = 83 Ounces
1 Hour " = 39 Gallons
1 Day " = 18 1/2 Barrels
1 Week " = 130 Barrels
1 Month " = 555 Barrels

This shows what the loss from leaking faucets will amount to.

The oil wasted is not the only loss, because there is a fire hazard created that is usually taken into consideration in establishing the insurance rate.

Tank storage with pumps also save considerable time, because the lubricants can be drawn from the tanks much more quickly than if it is necessary to wait for them to flow, particularly in cold weather. Also the requisition can be filled by means of a pump while a man is waiting without his wasting an excessive amount of time. In addition, there is no spillage and any drip runs back either into the tank or into a waste. In this way it is not necessary to use sawdust on the floor, which immediately takes away an important fire hazard. This also permits and encourages better housekeeping.

These tanks or containers are usually placed in multiple or in batteries of a number of compartments or tanks of the most advantageous sizes to store the different materials handled. Several of these storage units are illustrated here. The illustration at the head of the article, for example, indicates the arrangement at the Automatic Electric Company, Chicago, Ill. In this case all of the oils or other volatile or semi-volatile liquids used in the plant are stored in this battery of oil tanks. The first tank at the right is a 230-gal. container, holding a special thinner. This has special provision for agitatting and circulating the liquid and is also vent-proof so that none of it will evaporate. The next is a 160-gal. cutting-oil tank. The remainder of the tanks are all of 120-gal. capacity. The tanks, beginning with the third, contain the following liquids: lubricating oil for shafts and machinery, dynamo oil for motors, another cutting oil, linseed oil, alcohol, lard oil, paraffin oil, a tank temporarily not in use, and turpentine. In cases where the liquid is very volatile the tanks are not vented and are evaporation proof. This is particularly necessary in the storage of paint and linseed oil.

This installation has been in use for a number of years and, according to those in charge of it, the elimination of the necessity of using sawdust on the floor was one of the important advantages resulting from the change; this not only improved the plant housekeeping but also reduced the fire hazard. Other noticeable results are the elimination of any argument as to whether a department is getting the amount of oil for which it is charged and the ease with which the inventory record and the quantity of oil on hand can be checked. A gage on each tank enables the storekeeper to read the number of gallons remaining in the tank at any time.

The drums or barrels of oil are rolled onto the skid at the right and lifted by a chain hoist which, because of the limited space, is suspended directly in front of the doorway and

so must be removed when not in use. It is usually possible to empty several barrels at a time and so make it unnecessary to place this hoist in position often. The barrel is rolled on the barrel track to the proper tank, the inlet opened, and the tap in the barrel removed. The oil flows down into the tank and the barrel is permitted to drain until empty. The measure on the tank may be used to check the accuracy of the invoice with the amount of oil that was contained in the barrel. However, at the plant of the Automatic Electric Company this is checked by weight. Each barrel of oil received is also tested to see that it comes up to the contract specifications under which it is purchased.

There are objections to purchasing lubricating oil from a variety of sources. One of the most important of these, however, is not often appreciated. For example, it is not always desirable to mix two different blends or types of oil. For this reason, whenever a new source of supply is obtained, or a different brand of oil is to be stored in the tank, it is always well to clean the tank out thoroughly first. It requires very careful tests to be sure that the new oil is of the same quality and will be as good as that which had been purchased previously. Two oils may look alike, "feel" alike and, in a large measure, test similarly in certain of their characteristics and qualities, nevertheless they may be made from entirely different petroleum sources and not give the same lubrication service on a bearing.

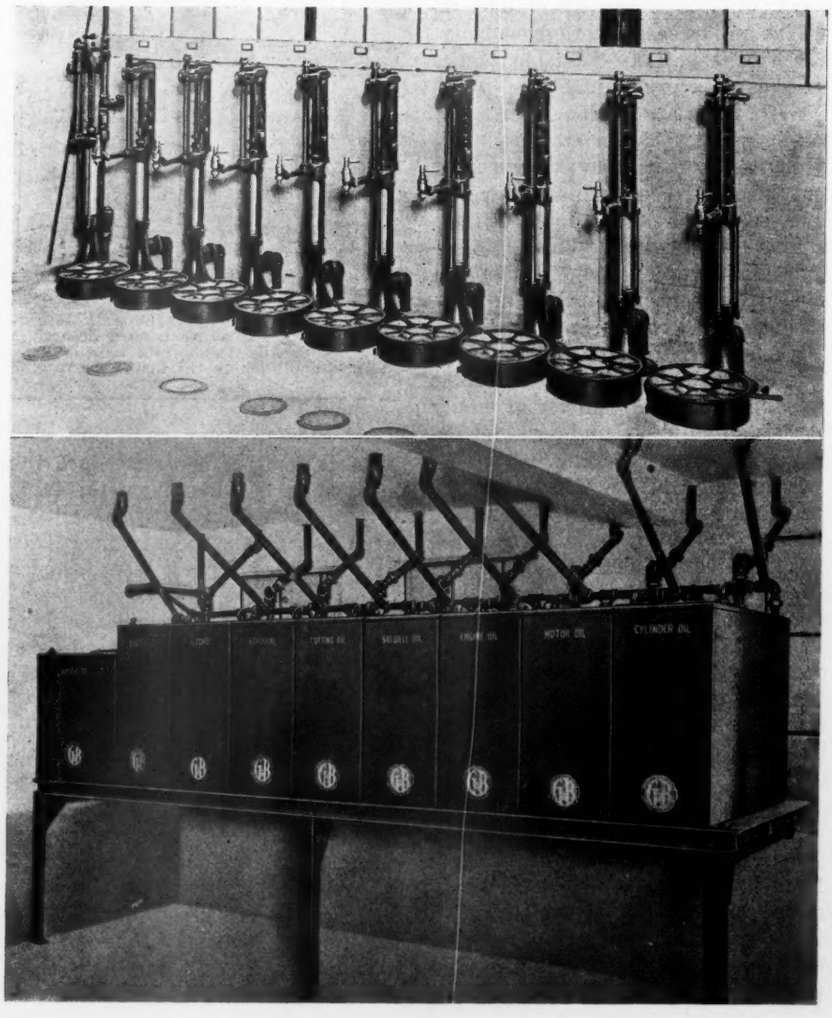
There is another point that sometimes must be taken into account in the installation of these tanks. This is best illustrated by the experience of the representative of one oil concern. The customer complained of water and mud in the oil when drawn from the tank. A check-up on several barrels of oil as received found no trace of water. The representative investigated, however, and he learned that the tanks had been stored out of doors for several days before they were placed in position inside the building. A check-up of

Happily, storage conditions such as this for lubricating and paint oils are rapidly disappearing in industrial plants.

the other tanks that had been installed at the same time showed that several others contained water and mud also. Those in charge of the plant then remembered that it had rained while these tanks were outdoors and that they had not been cleaned and emptied before installing. The danger of this is greater in connection with underground tanks, which sometimes lie around for a week or more before they are buried.

Underground storage is used for either or both of two reasons. Such a procedure is required in a number of the larger cities and by many fire insurance companies in connection with the more inflammable oils such as naphtha, linseed oil, turpentine, benzine, and so on. This is not often required of the lubricating oils, but it is sometimes desirable when they are bought in carload lots and stored in quantities, because then the tanks can be located out of the way more conveniently than if placed above ground. Also, the tank car can be drained by gravity. Carload purchases and deliveries have a price and freight differential that will help pay for the installation provided a sufficient quantity is used to make such an investment worth while.

The most common reason for using underground storage tanks is



Frequently space considerations do not permit placing the tanks in the storage room.

In such cases, the outlet pumps may be located one or more floors away from the tank, which is either placed in the basement or, with the more inflammable liquids, placed outside. This is a Gilbert & Barker battery storage installation on the first floor and basement of the Bethlehem Foundry & Machine Company.

lack of space inside the building. Frequently, however, these tanks are placed in the basement. This conserves floor space because, if necessary, a sub-basement can be excavated to hold the tanks. Also, much less floor space is required than when the tanks are placed on the floor instead of underneath the floor or in the ground.

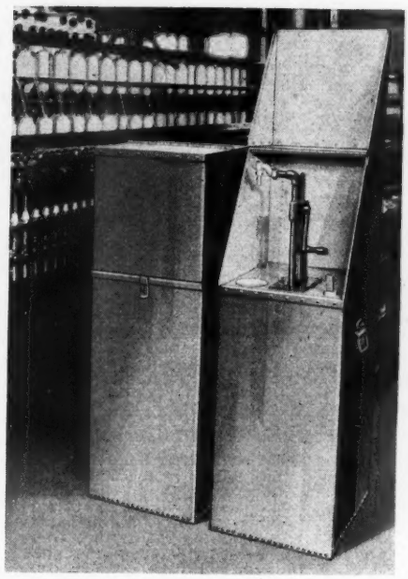
It is possible, by using power-driven pumps, to place the outlets of these tanks at various locations in the building, even often several hundred feet away. This is not so commonly done with lubricating oils as with some of the other oils that are used quite generally in the plant.

When deciding upon the type of storage installation or method of control of the lubricant, the question often arises whether to have one central distributing point or a central distributing and receiving store with several branch distribution stores. The answer to this question should always be based upon the conditions surrounding the plant and the operation involved.

To cite an example, a Mid-Western steel mill originally installed a central oil storage and issued all oils on daily requisition. Plans are now under way to change this somewhat so that, although the oil is all received and issued from the central storeroom, a number of sub-storerooms are placed at carefully selected points in the plant. Oil is still to be received in carload lots, but is not to be sent to the sub-storerooms in less than barrel lots. The auxiliary storeroom, in turn, issues the oil in smaller quantities as required. Each of these smaller auxiliary storerooms has its battery of oil tanks and pumps.

In other plants it has been found desirable to place pump outlets at each floor and have a single storage tank in the basement feeding to all of the separate outlets. However, in any of these cases the storage should not be open on a "help-yourself" basis, except possibly where only one or two men have access to it. Even then this man or men should keep a record of what is used. Where kept in Stores Departments the oil should be issued on requisition only and by or under the direction of authorized representatives of the Stores or Maintenance Departments.

At the East Pittsburgh plant of the Westinghouse Electric & Manufacturing Company the lubricating and other oils are handled from a central oil house. On an average about 5,000 gal. per month of one type of lubricating oil is used. This is ordered in tank-car lots and a storage capacity of 8,500 gal. is provided. There are three outlets for the distribution of this material to the various departments: One is on the first floor of the oil house above the storage tanks; the two others are the outlets of pipe-line connections that are placed approximately half a mile from the central oil house to give more central location for distribution to the various shops. Material is delivered by motor trucks from the most convenient of these three

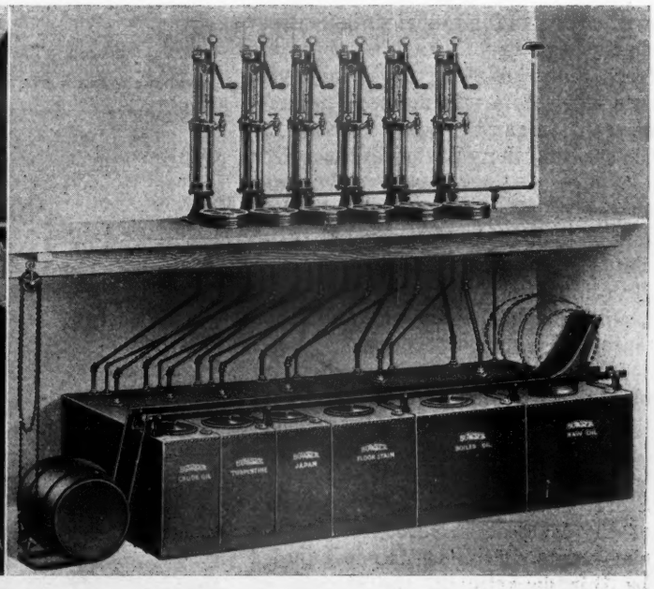


Lubricating oil is always convenient in this textile mill, but cannot get dirty.

Instead of providing a main central storage and issuing oils to the various departments in small quantities, a small, totally inclosed Bowser tank is placed in the department. The oiler can go directly to the tank and fill his oil can whenever necessary. The cover can be closed down and locked, if desired.

The method of handling grease in one plant.

This special grease pump and drum truck are used for oil and grease storage at the Bassick Manufacturing Company, Chicago, Ill. The operator is filling the portable filler tank, which is carried on into the shop and used for filling the Zerk pressure grease gun.



This shows the saving in space made possible through placing the tanks in the basement and the outlets on floors above.

This Bowser installation consists of a battery of six tanks and pumps. The method of emptying the barrels is well shown. Tanks of various capacities are used to fit the storage requirements and correspond with the amount of liquid handled. The mistake is sometimes made in not ventilating or keeping the basement or vault in which the storage tanks are placed clean and dry.

oil stations to the proper departments.

The department ordering lubricants issues a works requisition on the Stores Department, specifying the quantity and grade of material desired. After this requisition is filled it is then forwarded to the office to go through the regular cost routine.

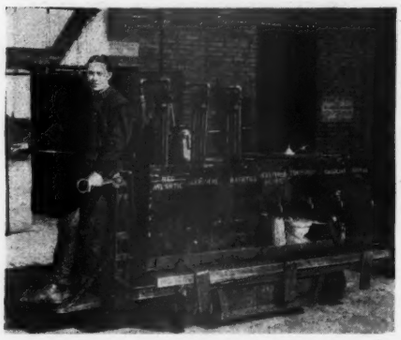
The savings made possible by using a comprehensive system for handling, storing, and issuing oils and greases were well shown in an article entitled "How $6,929.06 Has Been Saved in the Purchase, Storage and Distribution of Lubricants," which appeared in the October, 1924, issue of INDUSTRIAL ENGINEER. This described the practice followed at the Allis-Chalmers plant in Milwaukee. The saving during the first year came within $461.42 of paying the entire cost of the new installation.

Briefly, the system followed at this plant is to have a central receiving and storing oil house with a battery of fifteen 120-gal. Milwaukee Tank Works tanks equipped with 1-gal. pump and hose connections. In addition, there are three underground tanks for the oils that are received in carload lots.

Instead of issuing all materials direct to the various departments from this central storeroom, 22 substorerooms are located about the plant. An electric truck that carries Milwaukee compartment tanks, as shown in an accompanying illustration, makes these deliveries daily in 2½ hr. Each oil, liquid, or grease is issued in various standard-sized units and no man is supposed to be given more than a day's supply. This method of handling lubricants insures that each man will have a supply of fresh material at all times, and yet cuts waste to a minimum. Furthermore, it is easy to keep a check on the consumption of lubricants.

The general practice as to who has charge of oil storage varies in different plants. A large number of plants place the storage under the direction of the General Storekeeper and handle it the same as any other material.

In a considerable number of other plants, particularly those in which the maintenance is of considerable importance, it is frequently the practice to have a special Maintenance Store, under the direct supervision of the Maintenance Department. In such cases, if lubrication is handled by this department, the storage of lubricating oil should go in the department. One of the big advantages of the separate Maintenance Store is that the Maintenance Department has access to it on Sundays, nights, and at other times when the remainder of the plant and general storeroom are not open.



Oils, greases and other similar supplies are distributed from the central storage to the 22 departmental stores on this electric truck.

This installation shows the method used at the Allis-Chalmers Manufacturing Company's plant in Milwaukee, Wis. Two Milwaukee tanks with compartments of suitable size are placed on the truck for this delivery. Previously 55 men made a trip to the central oil house daily. Now one man with the truck makes the deliveries in 2½ hr. This has resulted in an important saving of time.

Grease lubricants offer a somewhat different handling problem than do the more liquid oil lubricants. For example, grease is seldom taken out of the container in which it is received until it is to be used or at least ready to be issued to the man who is to use it. One of the most important things to consider in contion with the storage of grease lubricants is to see that the covers are kept closed on the containers so that grit and dust will not get into the lubricant and make it unfit for its intended purpose.

Grease should be handled on requisition from the same stores and by the same routine used with issuing oil. It is seldom desirable to handle and store grease lubricants in the factory proper, because of the increased amount of dust in the atmosphere and the greater likelihood of its getting into the grease whenever the container is open. One of the accompanying illustrations shows the method recommended by the Bassick Manufacturing Company for the handling of grease when it is purchased in drum lots.

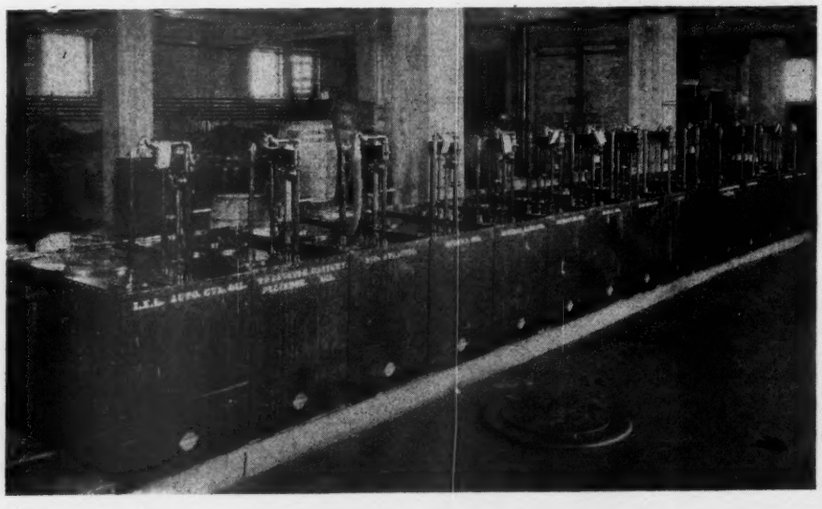
This outfit consists of a truck and a special pump for removing the grease and filling the smaller portable container that is taken around the plant by the oiler and used to refill the pressure gun. Another method of handling grease is to use, instead of the small handgun, an extra-large pressure device that has a chamber holding a large quantity of grease and so requires comparatively few refillings. The operating convenience should be taken into consideration very carefully whenever deciding upon any type of such equipment.

EDITOR'S NOTE—Acknowledgment is given to the following companies for supplying illustrations and information in connection with this article:

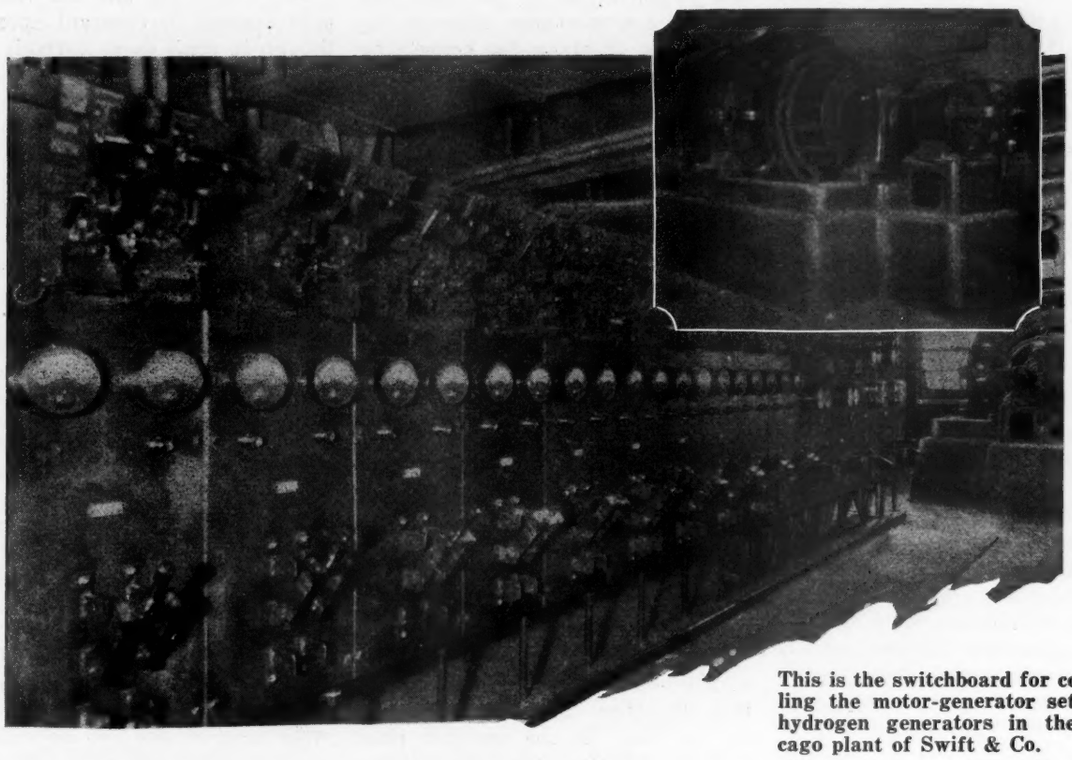
Bassick Manufacturing Company, Chicago, Ill.; Bennett Pumps Corporation, Muskegon, Mich.; S. F. Bowser & Company, Inc., Fort Wayne, Ind.; Gilbert & Barker Manufacturing Company, Springfield, Ohio; Milwaukee Tanks Works, Milwaukee, Wis.

The main oil house of the Allis-Chalmers Manufacturing Company.

Here fifteen 120-gal. Milwaukee tanks are used in the central storage of lubricants and other oils. The storage truck is loaded up here and makes the deliveries to the various sub-departmental stores. In addition, large underground tanks are used for liquids handled in large quantities. This permits buying in carload lots, which makes a saving of about 5 cents per gallon.



Midwest Engineers Discuss Power Problems That Confront Industry



This is the switchboard for controlling the motor-generator sets and hydrogen generators in the Chicago plant of Swift & Co.

There are two of these motor-generator sets, one of which is shown in the insert, which are rated at 700 kw., and are driven by 2,200-volt synchronous motors. They supply direct current at 120 volts, for the production of hydrogen which is used in solidifying vegetable oils in the manufacture of shortenings and other products.

THE second annual Midwest Power Conference was held in connection with the Midwestern Engineering and Power Exposition, or Chicago Power Show, at the Coliseum, Chicago, Ill., Feb. 15 to 19, inclusive. This conference was sponsored by the local sections, regional and professional divisions, of the American Institute of Electrical Engineers, American Society of Mechanical Engineers, American Institute of Mining Engineers, National Electrical Light Association, Western Society of Engineers, and National Safety Council.

At the Power Show 260 of the leading manufacturers demonstrated the latest equipment and practices in connection with power generation, distribution and utilization. This was a considerable increase over the number of manufacturers, 175, who had exhibits at the Power Show a year ago.

On the second day of the conference power problems in various industries were discussed from the standpoints of generation and utilization. In the following abstracts of these discussions, those portions of the papers dealing with the generation of power have been omitted, except where this is almost inseparably linked with the application. Likewise, the problems involved in the utilization of heat, which is so closely connected with some of the industries discussed, are merely touched on in these abstracts, although in some cases this subject was treated quite fully in connection with the problems incidental to the generation of power.

The subjects selected for this discussion are those which are very closely tied up with the industrial developments of the Middle West: steel mills, food industry (corn products), paper and cement mills, and the packing industry. It is quite fitting that the industrial men in the Middle West should have this opportunity to see the latest developments in equipment for the generation and utilization of power, and exchange their experiences through the medium of the papers and discussions that were presented.

It is stated that the immediate Chicago region has the greatest per capita utilization of electrical energy of any section of the world—1,050 kw.-hr. per capita per year.

The central district contains the greatest transmission interconnection system under one interest of any place in the world and the largest generating station in the country is in the making.

The formal program of papers and discussions was supplemented by inspection trips to various public utilities and industrial plants.

Power in the Packing Industry

By C. H. KANE

Manager, Construction Department, Swift & Co., Chicago, Ill.

SYSTEMS involving the generation of power in the packing industry are confronted with the great difficulty of bringing the requirements of steam for processing and heating, which are necessary about 8 hr. a day, in balance with the power requirements of refrigerating machines, pumps and a portion of the manufacturing load that is required over the 24 hr. It has been found that the balance is in favor of using central station service for power requirements, where satisfactory service and price schedules are available, and generating steam at low pressures for processing, instead of trying to generate all the power.

In 1915 our Chicago plant tried out central station service to the extent of about 2,500 kw. demand. Our load has now increased to 10,000 kw. demand and the load factor has increased from about 40 per cent to about 65 per cent. Central station service has been profitable, economical, and extremely convenient.

Electrification of our present refrigerating machines will be considerably hastened by the development by electrical manufacturers of slow-speed synchronous motors, reasonable in cost, from 55 hp. to 1,200 hp. rating, operating at a speed of about 60 r.p.m. We have about 5,000 hp. load of this character in Chicago, and similar loads on a smaller scale in all of our large plants. We have installed a number of medium-speed refrigerating machines developing from 400 to 500 tons of refrigeration per unit and mounted a synchronous motor on the shaft. By dropping the connecting rods and the valve gear rods on the cross-compound engine, the synchronous motors can be used to drive the compressors very satisfactorily. During the winter months we connect up the rods and the valve gear on the steam engine and use the exhaust steam. Either prime mover takes the load in case of accident. This procedure, however, represents a heavy initial investment which is justified only where a low power rate is available.

I believe that the meat packing plant of the present and the future will ultimately operate every power-driven piece of machinery, whether it be for mechanical purposes, or for pumping, mechanical refrigeration, intraplant transportation, electric lighting and certain forms of heating, from central station service.

Manufacturing power will be understood to include the power used from the time the stock is received on the hoof at the packing plant until it is slaughtered, dressed, refrigerated, loaded into cars or trucks, and sent away to the consuming public, as well as that consumed in working up the byproducts and the inedible products. Animals, through the killing and dressing operations and into the refrigerating rooms, are lifted with motor-driven hoists and carried on motor-driven dressing chains. Byproducts are processed by motor-driven equipment. The Sausage Department, for example, uses a large amount of power for grinders, food choppers and stuffers. The Lard Refinery uses power for operating lard chilling rolls, pumping, conveying and other machines. The motors driving these various machines range in size from 1 hp. to 150 hp. and for the most part operate at constant speed, although in some cases variable speed is used.

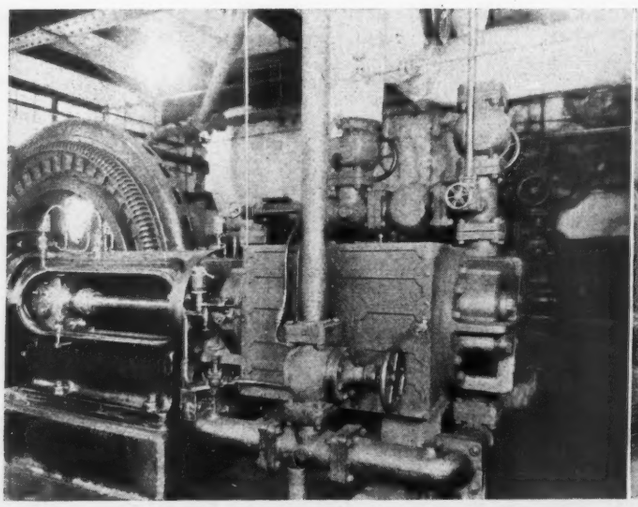
In the Chicago plant the total horsepower represented by refrigerating, pumping, electrical drives for manufacturing, and so on, will aggregate about 30,000 hp. which is divided as follows:

- Steam-driven refrigerating machines about 8,000 hp.
- Combined steam-driven and electrically-driven pumping equipment about 5,000 hp.
- Electric power used for manufacturing, produced by our own power plant about 3,000 hp.
- Electric power used for manufacturing, supplied by central station service about 12,000 hp.

The electric power generating station is equipped to generate about 6,000 kw. and our agreement with the central station provides that we will operate during their peak period with our station as a part of their stand-by power; during the fall and winter months we operate in parallel with their service. In December we

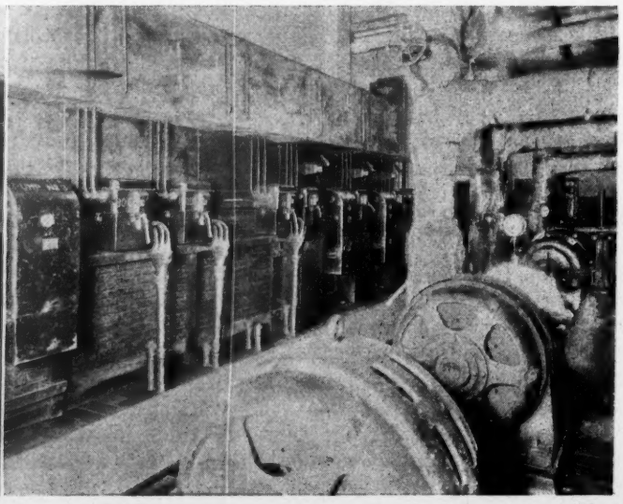
Here a standard, medium-speed, refrigerating machine is driven directly by a synchronous motor mounted on the shaft.

The flywheel is entirely eliminated and the flywheel effect is provided by the rotor of the motor. This is a very compact unit requiring only 588 sq.ft. of floor space and develops 400 to 500 tons of refrigerating capacity.



Part of a battery of nine motor-driven brine pumps.

Each of these pumps has a capacity of 2,000 gal. per min., and is driven by a 200-hp. squirrel-cage motor. This is a very desirable load for central service and with a constant-speed motor and constant head, the power factor will average about 93 per cent. A similar installation of pumps supplies the Chicago plant with 10,000,000 gal. of water per day.



operated on peaks with our power plant over a period of 2 hr. per day for several days during the month. The total power sold to the central station for the month amounted to 25,000 kw.-hr.; during this same period we purchased a total of 3,000,000 kw.-hr.

To supply our Chicago plant with water requires an installation of pumps with a capacity of some 10,000,000 g.p.d., equivalent to the consumption of a city with upwards of fifty thousand people.

Vertical, motor-driven turbine pumps are used in wells ranging in depths to 250 ft. Drilled wells from 600 to 2,000 or 3,000 ft. in depth are operated by the air-lift system. Two-stage compressors connected to medium-speed synchronous motors supply the air.

Direct current for the electrolytic dissociation of water to produce the hydrogen used in the solidification of vegetable oils in the manufacture of shortenings is obtained from two 750-kw., 120-volt generators, each driven by 2,200-volt synchronous motors operating at 100 per cent power factor and 100 per cent load factor.

For intraplant transportation, the electric tractor equipped with storage batteries is rapidly and economically replacing hand trucking and teaming. In the operation of 50 tractors in our Chicago plant, a charging station that will simultaneously accommodate 40 tractors is provided so that the charging can be entirely done off-peak. Each tractor will operate over a period of 8 hr. continuously without recharging and will consume a total of 1,500 kw. on the average run of 10 hr. per day.

These tractors, when operating for long and short hauls, and on grades not exceeding 5 per cent, will handle easily four trailers or a total of 6,000 lb. at a speed of 6 m.p.h. Special elevators with platforms 6x45 ft. designed to accommodate the entire tractor train without uncoupling the trailers are used in our Chicago plant.

Use of Power in Steel Mills

By WILFRED SYKES

Assistant to General Superintendent, Inland Steel Company, Indiana Harbor, Ind.

PROBABLY the most important item in the development of the industry has been the ready availability of power, which can be substituted for human effort. The increasing growth of the steel industry has paralleled the growth of the power industry. With each great improvement in the development and distribution of power, and the facility with which power can be applied to mechanical devices, there has been a corresponding increase in the production of the industry, coupled with an improvement in the working conditions and the standard of living of those employed in it. This has also been usually accompanied by a reduction in the cost and selling price of the product. Figures from one plant indicate an increase in production per man of about 35 per cent within the past 10 yr., in spite of the elimination of the 12-hr. day. European plants, which are not so completely equipped with labor-saving devices, have a production per man of only about 40 per cent of what we obtain.

At the present time the steel industry is largely electrified. About 35 yr. ago, the first efforts were made to use electric motors. The electric motor made the modern traveling crane possible, and this was the first main application of motors in the steel mills.

In the early days power was developed in the mills by direct-current generators driven by reciprocating engines. The units were usually small and frequently scattered in groups over the plant, so as to limit the distance power had to be transmitted. Later the practice changed to the use of alternating-current generation and distribution with converting arrangements to provide direct current where needed. In general, it has been found that for a large proportion of auxiliaries, direct-current motors have more desirable characteristics than alternating-current machines.

It is estimated that the total amount of power used in the industry in 1926 was equivalent to about 7,000,000,000 kw.-hr. Approximately 75 per cent of the power was generated in the mills and about 25 per cent was supplied from outside sources, largely from central station plants. The approximate rating of motors used in steel mills is 3,500,000 hp., of which over 1,000,000 hp. are driven by purchased power.

The power required for driving rolling mills varies with the type of mill and its product. The largest units are used with the reversing mills, the motor driving the rolls developing momentary outputs of 10,000 to 15,000 hp., with an average load of 6,000 to 7,000 hp. For driving other mills the peak loads are not so high, but the average load may be in the same order. The largest continuously-rated motor installed at present for driving a mill is 9,000 hp., but frequently several motors are used to drive different units of a single mill and the total may be much higher. The service of reversing motors is probably the hardest work performed by electric motors on any application. It is interesting to note in this connection that not only has the motor successfully performed this severe duty, but it has enabled greater production to be obtained at lower cost.

Many of the continuously running mills are driven by constant-speed motors, but there is an increasing use of adjustable-speed motors to enable mills to be run at the best speed for the particular product being rolled. With constant-speed motors the speed of the mill is usually a compromise between that required for the lightest and heaviest sections. Adjustable-speed drives allow of better production in many cases. As alternating current is practically universally used for power purposes various schemes have been evolved to obtain adjustable-speed drives, all, however, involving undesirable complications. There has, therefore, been a tendency in recent practice to use direct-current motors with either rotary converters or motor-generator sets to convert to direct current at the mill. Such drives are not quite so efficient as the various alternating-current combinations, but have the advantage of simplicity.

For a great many auxiliaries, where the service requires frequent starting or reversal, especially sturdy motors have been developed. Many applications in steel mills can be taken care of with ordinary commercial machines, but most of the auxiliary drives around the mills proper have special mill-type motors. These auxiliary drives usually do not exceed 100 to 150 hp. in single machines. The amount of power used for auxiliary purposes in steel mills is a very large proportion of the total, frequently amounting to one-third or more.

Power in the Cement Mill

By J. H. LENDI

Chief Electrical Engineer, Universal Portland Cement Company, Chicago, Ill.

A CEMENT mill, when considered as a power load, is unique among industrial plants in that it operates at an exceptionally high load factor over a 24-hr. day. Any departure from 100 per cent daily load factor is caused by incidental operating difficulties and not by essential interruptions in the process. Moreover, this condition persists over weeks and months except as influenced by holidays.

In a year's operation the load factor is lowered because of a seasonal variation of demand for cement. An annual load factor of 75 per cent is usually obtained, against a monthly factor of 80 per cent, which is about the highest that may be expected.

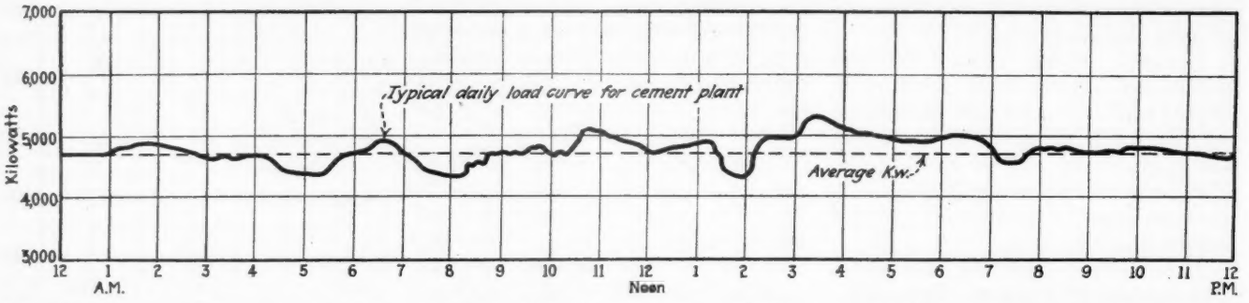
Not only is the rate of use of energy uniform, but also the consumption of energy is large, as may be realized when we consider that during the year 1926 the cement industry of the United States consumed more than 1,500,000,000 kw.-hr., the equivalent of about 2½ per cent of the electric energy generated by all light and power utilities. As an example of this remarkable load condition the accompanying chart gives a typical daily load diagram taken from actual operations, which indicates a load factor of 89 per cent.

The load factor over the year as measured by the two highest average daily kilowatt demands against the average kilowatt load over the year is, in this case, over 71 per cent. A load of this sort at 80 per cent power factor is, therefore, very desirable from the standpoint of the power sellers. Unfortunately for them, however, the cement mill has the ability to furnish its own power practically as a byproduct of operation, due to the waste heat of the cement kilns.

The manufacture of cement consists, briefly, of grinding and mixing of the raw materials, burning them in a kiln, and the grinding of the finished product. Coincident with the preparation of the raw materials coal is also powdered for drying and burning these raw materials.

To make the final product, cement, it is again necessary to repeat the grinding operations on the clinker after burning, which requires the expenditure of 7 kw.-hr. per barrel of cement in addition to the 10 kw.-hr. which have been already used, including all incidental power uses before the raw material becomes clinker, thus making a total of 17 kw.-hr. per barrel of cement. The process of burning is essentially continuous and, therefore, requires continuous preparation of raw material and also the final grinding of the finished product. This is the reason for the high load factor found in cement mills.

It would be desirable to be connected with another power system that could take the excess of power generated and serve as a source of supply when momentary shortages occur. Results have been published concerning other installations, which put the upper limit of cost of power generated from byproduct heat at 0.75 cents. It is indeed a poor installation or operation that cannot equal this. If power were to be purchased, it would necessarily have to be as low as this cost of byproduct production.



Curve indicating the practically constant daily power demand in a cement mill.

Use of Power in Paper Mills

By V. D. SIMONS

Consulting Engineer, Chicago, Ill.

NEWSPRINT and other papers made principally of mechanical pulp or "ground wood" require energy so out of proportion to heat that they cannot be made in a competitive market without the use of cheap hydroelectric power. From pulpwood to finished paper requires about 1,700 kw-hr. per ton of paper and only about 10,000 lb. of steam—an impossible water rate for steam-electric generation.

Book paper and paper board mills where exhaust steam is usable to cook out ink, sizing, and dirt from old paper stock, can be operated on 550 kw.-hr. and 12,500 lb. of steam per ton of product. Book paper mills in conjunction with soda pulp mills, where exhaust steam is usable to prepare the cooking liquid and for evaporation, require about 635 kw.-hr. and 15,400 lb. of steam generated at 400 lb. gage pressure and 650 deg. F. to produce a ton of paper. Paper or board mills located in a city often find it advisable to generate the direct current for driving the paper machine with a non-condensing, direct-current turbo-generator and purchase the requisite alternating current for other motor drives.

Theoretical balance of demands for heat and mechanical power over a 24-hr. interval must take into account those periods when electric power is at a peak and the exhaust steam requirement is low, and *vice versa*. The balancing of heat and power demand is, perhaps, the most vital problem to be solved by the paper mill engineer.

As stated, the energy requirement of newsprint production, commencing with cordwood, is far greater than for any other variety of paper. The requirement for grinding the wood is 1,300 kw.-hr. of the total 1,700 kw.-hr. per ton of product. The en-

ergy loads of other paper mills are nominal, amounting to about 200 kw.-hr. per ton of paper for the beater room, which is the largest departmental load.

There is a reasonable hope that the characteristic load of all paper mills will be reduced as much in the future as it has been in the past. New inventions and the development of old ones, quite unlike the beaters and jordans, to obtain the same results with the expenditure of less energy, are in process of adoption.

A considerable pumpage load is common to the beater and paper or board machine rooms. The operation of the pulp presses also requires considerable power, as do certain mills making highly compressed and glossed or supercalendered paper and those employing a large number of cutters for converting rolls into sheets.

The chief power load of the mill, after that of the beater room, is from the drying section. This load is due to bearing friction and overcoming the inertia of the drying cylinders. Beyond the relief obtainable from roller and other bearings, which are better than the standard journal, not much reduction in energy requirement may be expected here.

The modern drive for paper and board machines is by direct-current motors so interconnected electrically that the relative speeds between the sections of the machine and the absolute speed of the entire machine are changeable instantly through a considerable range, at the will of the operator. This corresponds to the old-time variable-speed steam engine, many of which are in service.

The special problem of steam and electric engineering with respect to pulp and paper mills is this: To reduce the energy requirement of the process, if by so doing the cost of fuel and boiler plant operation can be diminished. If not, reduce the heat requirements of manufacture; if that be impossible, find a use for the energy available from the necessary steam and apply it to the reduction of labor costs in the mill. Or, balance the requirements of steam and energy by devising ways and means of using any unavoidable surplus of one or the other to attain increased production of paper. The solution of these problems affords opportunity to practice the best and latest developments of the art and science of engineering.

Power in the Food Industry

By JOS. J. MERRILL

Chief Engineer, Corn Products Refining Co., Chicago, Ill.

IN THE food industry, as represented in the manufacture of corn products, the use of steam and heat is of much greater importance than the actual use of mechanical and electrical power. Progress, therefore, in this industry has been largely toward more economical generation of steam, and better application of steam and heat in the manufacturing processes. For example, in 1907 when this company began making a study of its use of power, a saving of 175 tons of coal a day in one plant was made on an expenditure of less than $500 through stopping the waste of steam in the manufacturing departments.

Up to that time little or no thought had been given by the men in charge of the factories to the efficient production or use of steam and power. The reason for this was that prior to 1907, managers, superintendents, and their assistants in all the factories were chemists, and had the control of everything in their hands. It was the chemist who developed the industry, and because a certain amount of chemical knowledge was necessary in the process, it was thought that he must run the

After the showing which had been made in this one plant in 1907, the production of steam and power and its use in all of our factories were put under complete control of an engineer, which in a few years brought about a marked change in the management of the factories. Ninety per cent of all the work involved in the manufacture of the products calls for engineering rather than chemical knowledge. Today, the managers, superintendents, and master mechanics of our factories are all engineers and they have all reached these positions by first learning how to make and use steam and power economically.

Costs of operation are based on the bushels of corn ground, which is the basic factor in the industry. In this industry the use of power is a minor element, but the use of heat and steam are of major importance. The plant, as well as the type of drive, must be designed with this in mind. A number of years ago the practice was to use steam-driven units scattered around through the plant to drive the various mills, pumps, and so on. Today, all pumping and generating equipment is concentrated in a single power plant. Mills and conveying equipment are motor driven.

Whereas 20 years ago 1,600 kw.-hr. and 7,800 boiler horsepower hours were required for every 1,000 bu. of corn ground, today, in a plant manufacturing the same product, every 1,000 bushels of corn ground requires 2,800 kw.-hr., but only 4,000 boiler horsepower hours. Large quantities of heated water are required in some of the processes and much heat for drying is necessary.

The reduction made in the consumption of coal has been followed by a reduction in the maintenance costs of our factories. In 1912, an assistant to the Chief Engineer of the Company was put in charge of the maintenance work in all factories. During the following year, 1913, the average maintenance in all our factories was 2.75 cents per bushel of corn ground. In 1926 the maintenance cost was 2.7 cents per bushel. Although the cost in 1926 was a fraction of a cent per bushel lower than in 1913, the comparative cost was much lower, when the cost of labor and material are taken into consideration during these periods. In 1926 our labor costs were 83½ per cent higher and material costs were 117 per cent more than in 1913. Based on 1913 labor and material costs, the maintenance cost in 1926 would have been 1.2 cents per bushel of corn ground, a reduction of over 1.5 cents, or $585,000 per year.

The good work that has been accomplished is due to a great extent to the way our engineering department is organized. There is a designing department where an entire factory or any part of one is completely designed; a construction department which does all the construction work (no outside contractors are employed on any of our work); the operating department which takes over the plant and operates it, when the construction work is finished; and the maintenance department. Each of these departments has an engineer in charge of it who has grown up in our business.

The Chief Engineer, who is responsible for all these departments, is also Chairman of the Manufacturing Committee, which controls everything having to do with the manufacture of all our products.

Factors that Determine Necessity for

Replacing Obsolete Equipment

ONE of the puzzling but important problems that has to be solved by every industrial operating executive is that of replacing obsolete electrical and mechanical power drive equipment. Barring complete failure or accidents that damage equipment beyond repair, it is possible to evade facing squarely the problem of replacement, for with proper maintenance attention it is possible to keep almost any piece of equipment in service practically indefinitely. To do this one must, however, be prepared to pay heavy operating and maintenance costs. On the other hand, to replace serviceable equipment without adequate justification is indefensible.

How, then, can the industrial executive determine when it is justifiable from an operating standpoint to replace equipment?

The answer to this question was sought from readers. Men in well-known plants were asked to enumerate the factors they consider to be the most important in determining the advisability of replacement. Supplementing these opinions, a number of manufacturers of equipment were asked to give their viewpoint on this subject.

Some of these answers were published in the article beginning on page 51 of the February issue. Other answers that have been received are given below.

In determining the need for replacement, H. D. FISHER, PLANT ENGINEER, *The New Haven Pulp and Board Co., New Haven, Conn., considers that trouble from the operating standpoint, and the amount of production delays are the principal factors to be considered. He also calls attention to the fact that there may be little economy in purchasing equipment that will eliminate a laborer, but require a more expensive workman to operate or maintain it.*

WE HAVE no definite schedule for replacing power drive equipment, as each case is judged as far as possible on its own merits. In a comparatively small plant such as ours this is not difficult, as certain men, the millwrights for each paper machine, the chief engineer for the power plant equipment, the electrician for the motors, and so on, are made responsible for maintaining their equipment in operating condition and advising of the necessity for repairs or replacements which they do not have facilities for making, subject, of course, to the general inspection of the superintendent and other higher officials.

Recommendations for replacing the equipment usually arise through these men or the superintendent when the amount of time required to keep the equipment in shape, or breakdowns resulting in loss of production, appear excessive.

The principal factors in determining replacement are trouble from the operating standpoint and loss of production; next to this, and usually associated with it, is excessive repair cost. Aside from its effect on these considerations age is of little consequence, as at times it seems as though the manufacturers employ their experience chiefly to see how much poorer and cheaper they can build their product and get by with it. In most of our equipment it is very difficult to obtain a sufficiently accurate measure of efficiency to warrant replacement on this ground.

Other things being equal, we prefer to buy equipment of the same make as we already have, providing it will give us sufficient duplication to reduce the storage of spare parts. Aside from this, the precedent of using the same make of equipment in choosing future equipment has no weight.

In purchasing new equipment we aim at minimum over-all cost, capital charges, power requirements, and repairs. In every case, the first consideration is continuous operating reliability, as in a paper mill the processes are so connected up that a shut-down of a comparatively small and inexpensive piece of equipment may tie up the whole mill and completely stop production. Reliability usually includes saving in maintenance and repair costs and, of course, design and construction which allow of easy access and ready repair are very important considerations. For minor auxiliary equipment which is used infrequently, first cost is more of a consideration, but the writer's experience has been that, within reason, price should be of no consideration whatever as compared with reliability and freedom from repairs. Of course, as between what are apparently equally well built and substantial machines, we would be inclined to purchase the lower priced one.

The matter of saving in operating labor affects the decision to replace equipment rather than the choice between different pieces of new equipment, but we find many of these arguments are illusive. There is often a tendency to eliminate a laborer by the purchase of a machine which eventually requires a much higher paid mechanic to run it or keep it in shape.

Operating trouble is a most important factor in determining replacement, says R. N. VINING, ELECTRICAL SUPERINTENDENT, *The Colorado Fuel and Iron Co., Pueblo, Colo. He describes the method used in estimating the present value of equipment in service, which forms the basis on which comparisons with new equipment can be made.*

IN THE replacement of equipment we consider trouble from the operating standpoint as a most important factor. Next comes age, in so far as it affects improvements in construction, standardization, and "quick change" features in the event of breakdown. In the case of control equipment, improved types of overload protection, acceleration features, plugging arrangements, automatic features and so on are important factors. Third, excessive repair costs and the general efficiency of the old equipment are both balanced against the cost of new apparatus.

We keep costs of equipment as follows: The value of the apparatus is determined by charging off a certain amount each year for depreciation. The amount charged off, plus interest on the invested capital represented by the present value, plus taxes, plus maintenance and operating costs give us a basis on which comparisons can be made. With these data the cost of operation, including all of the above items plus the savings or the value of the increased production obtainable from new designs, helps considerably in deciding the best equipment for us to use.

If we find that one piece of equipment slows down a process involving other equipment, either from the operating standpoint or due to trouble, improvements to this drive receive first attention.

Excessive repair cost and operating trouble are considered by R. R. SCHELLENGER, ELECTRICAL ENGINEER, *Elk Horn Coal Corp., Wayland, Ky., to be the most important factors in deciding the necessity for replacement. In his case power costs are so low that any possible saving is not a decisive factor in the selection of new equipment.*

WE DO not have what could be called a definite schedule for replacement of equipment, but we do keep records which have a direct bearing on this question, and recommendations for replacement usually originate in my office.

We keep a record of the repair cost on all important pieces of equipment, and consider that excessive repair costs and trouble from an operating standpoint are the most important factors in determining the necessity, or advisability, of replacement. The age of the equipment cuts but little figure if maintenance is properly looked after. Furthermore, our power costs are so low that the item of increased depreciation on a more efficient, but more expensive, machine will outweigh the saving in power costs.

As a general rule, we replace obsolete equipment with apparatus of the same make, although this depends entirely upon the performance record of the machine in question. In any event, saving in operating labor, in maintenance and repair costs, and desirable features of design and construction, rather than first cost, are the determining factors in the selection of new equipment. It is rather difficult to say which of these three factors is given the most weight, as this depends on the location of the equipment and the kind of service it renders.

If it can be shown that the cost of replacing or altering equipment can be paid for out of savings or increased production within a year or so, CARL RETTER, CHIEF ELECTRICIAN, *Allied Paper Mills, Kalamazoo, Mich., makes the change without further delay. Operating troubles and suggestions for improvements are discussed with department heads in weekly meetings.*

WE HAVE weekly meetings of the foremen of the different departments. Here the problems of these departments are discussed, and all weak points are brought to light. If we find that someone has had trouble with any of the equipment, or that he has any difficulty in keeping up production in his department, the matter is at once taken up by the production manager, master mechanic, and myself. If we find that a certain machine or part has given more trouble than should be expected, or that a larger or faster machine would increase production, or possibly changing controls to a more convenient place, or replacing manual with automatic, float or pressure control would be advisable, the matter of cost is gone into. If it can be shown that the investment will pay for itself in about one year the change is made without any further discussion; if the expenditure is a large amount requiring two or more years to pay for itself, the matter is taken up with the management.

If any of the men have any suggestions to offer, these are given careful consideration.

The cost of all repairs to equipment is kept on file; production time lost, with time required to repair equipment that has failed, is also filed.

In determining obsolescence, I do not see why age of equipment is to be considered, if it does not give trouble from the standpoint of operation or excessive repair costs, assuming, of course, that it does not hold up production to the extent that new equipment would more than pay for itself.

In replacing equipment, what we buy is governed by past experience and the possibilities that seem to be offered by new devices available.

In the selection of new equipment, saving in operating labor and low maintenance and repair costs should, in my estimation, be the governing factors.

Improvements in the design and construction of both a.c. and d.c. motors make extensive repairs to motors ten years or more old questionable from the standpoint of economy, according to J. W. COREY, ASSISTANT SALES MANAGER, *The Reliance Electric & Engineering Co., Cleveland, Ohio.*

THE electrical industry is so young and the life of an electric motor is so long that replacement of old motors has not until lately been an item of interest to the average plant man.

We have had, of course, the change from direct to alternating current in many plants, but in this case the primary reason has been to secure central station power at rates cheaper than an isolated plant could make it. Most of these changes swept too clean and it has usually been found necessary to convert some of the alternating current back to direct current to take care of adjustable-speed and other drives.

It is questionable whether it pays to rewind stators and replace bearings on squirrel-cage motors of 5 hp. rating and less that are ten years old. Few motors built before that time had cast or welded rotor end ring construction, and although the old soldered rotors can be welded they are inefficient and the power factor is poor. Furthermore, such repairs are expensive.

Again, ten years ago ball bearings in motors were very costly. The lower maintenance on motors equipped with that type of bearings is quite universally admitted and new motors can be purchased with them at comparatively slight extra cost.

To illustrate, I will quote the prices on two sizes of three-phase, 60-cycle, 220-volt squirrel-cage motors in this class, as given by a Cleveland repair shop:

Motor, 1,800 Rp.m.	New Motor with Ball Bearings	Rewinding and New Sleeve Bearings
1 hp.	$39	$33
3 hp.	52	42
7½ hp.	79	60

It will be noted that as the motors get larger it becomes well worth while to repair them, but the smaller machines should be replaced with new motors unless mounting limits make this inadvisable.

On direct-current motors with more complicated windings far greater strides in improvement have been made in the past 10 to 15 years. Commutating poles have come into use, giving longer life and lower maintenance cost than was possible with older motors. Insulation of brush studs, field and armature coils has been improved. Better commutators are being manufactured, and anti-friction bearings in motors eliminate oil and lubrication troubles.

It is my opinion that a careful analysis of costs will show that with any direct-current motor from 10 to 15 years old, or older, that does not have interpoles the following statements hold true:

(1) If a new commutator is necessary a good many cuts must have been taken off, denoting much sparking and consequent need for careful maintenance.

(2) Megohm readings on the fields will show that they have about reached their limit of usefulness.

With these points in mind determine the cost of all repairs that must be made soon. Check their cost, and the possible loss of productive time against the cost of a new motor, and it will be found that it will pay to scrap any direct-current motor up to 30 hp. rating that has reached this condition.

It is not the intent of this article to limit the life of motors to 10 or 15 years, as we know of many motors 25 to 30 years of age that are still operating satisfactorily and will continue to do so for years to come.

However, I should like to bring to the attention of operating executives a few of the conditions under which repairs cease to be economical.

On the other hand, proper inspection and prevention of trouble can cut maintenance costs in two and double the life of a motor.

If a motor is in a dirty place, clean it often and try to design a protective cover of some kind. The motor manufacturer can probably offer helpful suggestions.

If a motor overheats find out the cause at once, correct the trouble and save a burnout.

If a direct-current motor is sparking, no matter how little, repair it at once. Sparking increases as the commutator gets rough and will soon make expensive repairs necessary, if the trouble is not corrected.

Proper attention to these three points will save you money:

(1) Frequent inspection of motors and control equipment.

(2) Cleanliness.

(3) Prompt correction of symptoms before actual trouble occurs.

Construction details of

Short-Throw Coils for Chorded Windings

together with examples of the savings in copper and other advantages obtained by the use of such coils

MANY of the present-day designs of induction motors and alternating-current generators employ short-throw coils in what are known as chorded windings. This construction results in improved performance, since the lessened length of copper wire reduces the heating effect and the shorter coil and end connections reduce the inductance of the coil ends. The combined effect is to lower the impedance of the winding, with improvement in power factor and efficiency. This article deals with the construction of short throw coils and the benefits obtained by their use.

By A. C. ROE
and
D. H. BRAYMER
Consulting Editor, Industrial Engineer

THIS article is written to assist those who have occasion to rewind standard present-day designs of induction motors for a different number of poles and are required to lay out new coils of the short throw type.

The following examples and the accompanying diagrams illustrate an easy and accurate method of laying out these short throw coils to secure the advantages that are possible through their use. Fig. 1 is constructed to show the plan view of the coil ends required for a ten-pole motor having 144 slots with different coil throws from full pitch of 1-and-15 to half pitch of 1-and-8.

The line *XX* represents the end of the slot sections of the coil and the line *FB* the distance between the line *XX* and the center line of the pin at the diamond point of the coil after being pulled to shape. This line *FB*, shown as *HT* (for height) in Fig. 1 and in Table I, also indicates the coil end extension beyond the cell sections. It will be used to show the reduction in over-all length of the short throw coils. This reduction in length is shown in Fig. 1 at the left, by means of the horizontal lines marked 1 to 8 through the center line of the shuttle pin after pulling.

The line *FB* also locates the center line of the coils, and each coil throw from 1 to 15 down to 1 to 8 is shown by the numbers 1 to 8 in the first column of Table I as worked out for each coil throw listed in that table.

The line *EG* in Fig. 1 for No. 8 coil pitch is for 50 per cent pitch, whereas the line *FB* is for full or 100 per cent pitch. The angle *ABC* in Fig. 1 gives the 1 to 15 pitch, coil end extension and the angle *AEF* gives the 1-and-8 pitch.

In Table I, column 1 lists the eight coil pitches considered from full to half pitch. Column 2 gives the coil pitches considered and column 3 the location of the center line of the coil pitch in each case. For example, in case 4, column 3 shows that the center line of this coil lies between slots 6 and 7 and the line *HT*-4 shows its location in Fig. 1. Column 4 gives the total over-all reduction in length—that is, the distance between the horizontal lines 1 and 2 times two. Column 5 lists the lengths of the line *HT* for each case. Column 6 gives the length of the line *D*, or the distance between the point *A* and the intersection of the line *HT* and the center line for the shuttle pin for each case. It is the length of this line that governs the length of the shuttle. Column 7 gives the length of the shuttle required. This is based in Fig. 1 on a 7-in. cell length for both sides and twice the length of the line *D* for each case. Column 8 gives the length in inches that the total length of the shuttle between the center lines of the pins (*L* in Fig. 3) is reduced by the reduced coil throw for each case.

From Table I it will be found that the 1-and-10 pitch reduces the over-all length of the coil $2\frac{3}{32}$ in. and cuts $3\frac{3}{16}$ in. off the shuttle. For each turn in the coil this represents a saving of $6\frac{3}{8}$ in. of the copper wire used.

A layout such as shown in Fig. 1 is not difficult to make for any coil and it is useful to obtain a coil extension that will give good clearance between the ends of a coil and the bearing brackets. In Fig. 1 it has been assumed that both coil cells are of the same length, whereas in actual practice one cell is longer than the other; this will change the actual dimensions given in Table I and in Fig. 1, but the proportions of savings will still remain the same. Also Fig. 1 does not show all of the savings to be made in the total copper

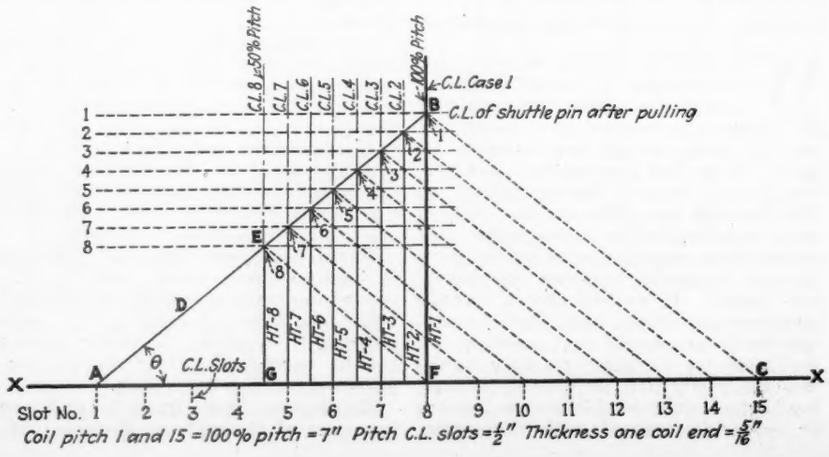


Fig. 1—Plan view of the coil ends required for a ten-pole stator having 144 slots with different coil throws from full to half pitch.

The line *XX* represents the end of the slot section of the stator and the line *FB* the distance between the line *XX* and the center line of the pin at the diamond point of the coil after being pulled to shape. The reduction in length of this line *FB* for the different coil throws is shown by the horizontal lines at the left marked 1 to 8.

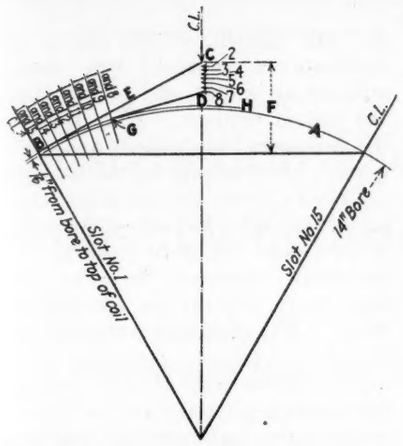


Fig. 2—This diagram shows that the shorter the coil extension and pitch the lower the diamond point of the coil can be to the bore of the stator.

The arc *A* represents the air gap line or bore of the stator and the line *H* the distance the coil lies above the air gap line, or about $\frac{1}{16}$ in. The line *BC* represents the top of the coil end for various coil throws with resulting differences in the length of the line *F* to bring the point *B* in Fig. 1 on *C* of this diagram above the air gap a sufficient distance to keep the coil clear at all points of the air gap.

length by chorded pitch windings, since the shorter the coil extension and pitch the lower the diamond point of the coil can be made in reference to the bore of the machine. This is shown in Fig. 2 and in Table II.

In Fig. 2 the arc *A* represents the air gap line or bore of the stator and the line *H* the distance the top of the coil lies above the air gap line. In Fig. 2 the center line has been kept fixed and the throw moved in a half slot pitch for each case. The line *BC* in Fig. 2 represents the top of the coil, and this line is usually made so as to keep the coil below the air gap line. For each case, then, the line *BC* has been drawn and the distance *F* measured and recorded in Table II; also the lengths of the lines *E* as *BC* or *GD* for each case have been added to Table II.

Table II also gives the difference between the line *BC* or *E* for the full pitch 1-and-15 and each possible throw down to 1-and-8 or half pitch. The maximum saving in the difference in line *E* for the 1-and-8 pitch is $1\frac{31}{32}$ in.

Thus from Figs. 1 and 2 it will be found that a short throw coil results in a shorter length of copper from the fact that any coil extension is composed of two factors: (1) The length of the line *AB* in Fig. 1 in a flat place and (2) the difference between *AB* of Fig. 1 and *BC* of Fig. 2 which is required to bring the point *B* in Fig. 1 or *C* in Fig 2 above the air gap a sufficient distance to keep the coil clear at all points of the air gap.

The layout of Fig. 2 is not a continuation of the diagram in Fig. 1, but represents figures taken at random to illustrate the points brought out.

In Tables III and IV it is assumed that the savings given in Tables I and II are for any one coil and the

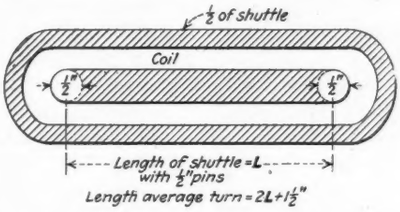


Fig. 3—A shuttle made coil showing the length of the shuttle (L) and the average length of the turns of the coil.

effects of the reduced or chorded pitch on the effective turns, line voltage and total length of copper in inches saved per coil are recorded. In both these tables under column 7 are listed the total lengths of copper per coil for each case. This was found by first assuming a coil having ten turns of one No. 9 B. & S. double cotton-covered wire arranged two wide by five deep. Since one insulated No. 9 wire has a diameter of about $\frac{1}{8}$ in., five such wires would be $\frac{5}{8}$ in. high. Then assuming a $\frac{1}{2}$-in. pin for the shuttle in Fig. 3, it is found that the average length of a turn of wire is equal to $2L$ and the circumference of a circle $1\frac{1}{2}$ in. diameter, which is about $1\frac{1}{2}$ in. Then L in Fig. 3 for each case equals L as in Table I plus twice the difference between line *E* as recorded in column 4 of Table II.

In Tables III and IV the first column lists the coil pitches in column 2. Column 3 gives the coil angle in electrical degrees; column 4 the cord factor for each case; column 5 the effective turns, which are found by multiplying the total turns per coil by the chord factor; column 6 the line voltage for each coil pitch, which is equal in each case to 220 times the chord factor; column 7 the total inches of copper in the ten coil turns for each case; column 8 the total number of physical turns per coil; column 9 the total savings in inches of copper per coil for each throw.

By studying Table III, it is found that case 4 reduces the total turns to an effective value of 9.32 or $9\frac{1}{3}$ turns, which reduces the line voltage to 205, or not quite 10 per cent, which should cause no trouble. The starting and pull-out torques will be increased, and from column 9 of Table III it is found that for case 4 a saving of $63\frac{3}{4}$ in. of copper is effective for each coil. By carrying the study further to Table IV it will be seen that the physical turns have been increased to a value that will raise the effective turns to give a working voltage for the coil throw used.

Then by comparing cases 6 and 7 it is found that the greatest saving is obtained with case 6, whereas case 7 shows a good saving and has a shorter coil extension than case 6.

By comparing case 4 with case 6 it is found that even with an added turn, case 6 shows a better gain in copper saved and also a shorter coil extension. Thus, all things considered, if there is room in this slot

Table I—Information on Short Throw Coils Based on the Diagram of Fig. 1. All Dimensions Are in Inches

Coil No.	Coil Pitch	Center Line of Coil Pitch	Reduction in Length of Coil	*HT*, Inches	*D* Inches,	Length of Shuttle	Reduced Length of Shuttle
1	1 and 15	1 and 8	...	$2\frac{31}{32}$	$4\frac{1}{16}$	16	...
2	1 and 15	1 and $7\frac{1}{2}$	$\frac{1}{16}$	$2\frac{31}{32}$	$4\frac{1}{16}$	$15\frac{15}{16}$	$\frac{1}{16}$
3	1 and 13	1 and 7	$\frac{1}{32}$	$2\frac{31}{32}$	$3\frac{31}{32}$	$14\frac{31}{32}$	$1\frac{1}{16}$
4	1 and 12	1 and $6\frac{1}{2}$	$1\frac{1}{16}$	$2\frac{31}{32}$	$3\frac{1}{16}$	$14\frac{1}{16}$	$1\frac{1}{8}$
5	1 and 11	1 and 6	$1\frac{1}{32}$	$2\frac{31}{32}$	$3\frac{1}{16}$	$13\frac{15}{16}$	$2\frac{1}{16}$
6	1 and 10	1 and $5\frac{1}{2}$	$2\frac{1}{16}$	$1\frac{31}{32}$	$2\frac{31}{32}$	$12\frac{31}{32}$	$3\frac{1}{16}$
7	1 and 9	1 and 5	$2\frac{1}{16}$	$1\frac{31}{32}$	$2\frac{1}{16}$	$12\frac{1}{16}$	$3\frac{1}{8}$
8	1 and 8	1 and $4\frac{1}{2}$	$2\frac{1}{16}$	$1\frac{1}{16}$	$2\frac{1}{16}$	$11\frac{31}{32}$	$4\frac{1}{16}$

Table II — Information on Short Throw Coils Based on the Diagram of Fig. 2. All Dimensions Are in Inches

Coil No.	Length of Line *E*	Length of Line *F*	Differences for Lines *E*	Coil Pitch
1	4	$1\frac{31}{32}$	...	1 and 15
2	$3\frac{1}{2}$	$1\frac{15}{16}$	$\frac{1}{2}$	1 and 14
3	$3\frac{1}{16}$	$1\frac{29}{32}$	$\frac{15}{16}$	1 and 13
4	$2\frac{15}{16}$	$1\frac{7}{8}$	$\frac{7}{8}$	1 and 12
5	$2\frac{7}{16}$	$1\frac{13}{16}$	$\frac{13}{16}$	1 and 11
6	$2\frac{1}{8}$	$1\frac{3}{4}$	$\frac{3}{4}$	1 and 10
7	$2\frac{1}{16}$	$1\frac{11}{16}$	$\frac{11}{16}$	1 and 9
8	$2\frac{1}{16}$	$1\frac{1}{2}$	$1\frac{11}{16}$	1 and 8

Table III—Saving in Copper When Winding Coil of Ten Turns of No. 9 B. & S. Gage Double-Cotton-Covered Wire

Coil is wound two wires wide and five deep, with different coil pitches, for a 144-slot, 10-pole stator.

Coil No.	Coil Pitch	Coil Electrical Angle, Deg.	Chord Factor	Effective No. Turns	Line Volts	Inches Copper in Coil	Total Turns	Saving Copper, Inches
1	1 and 15	87½	0.99905	10.0000	220	345	10	....
2	1 and 14	81¼	0.98836	9.8836	217.44	311½	10	33¾
3	1 and 13	75	0.96592	9.6592	212.50	298¾	10	56¼
4	1 and 12	68¾	0.93201	9.3201	205.04	281½	10	63¾
5	1 and 11	62½	0.88701	8.8701	*195.14	262½	10	82½
6	1 and 10	56¼	0.83147	8.3147	*182.92	243¾	10	101¼
7	1 and 9	50	0.76604	7.6604	*168.53	225	10	120
8	1 and 8	43¾	0.69151	6.9151	*152.13	206¼	10	138¾

*Not enough turns to meet line voltage conditions. See Table IV for required turns per coil.

Table IV—Same as Above Except for Increase in Turns per Coil to Give Working Voltage for Coil Throw Used

5	1 and 11	62½	0.88701	9.75711	214.65	286½	11	58½
6	1 and 10	56¼	0.83147	9.14617	201.22	264¼	11	80¾
7	1 and 9	50	0.76604	9.19248	202.23	270	12	75
8	1 and 8	43¾	0.69151	8.98963	197.77	368¼	13	76¾

for the extra turn, case 6 of Table IV would give the maximum savings and the shortest coil extension.

It will be observed that a few sketches and tables such as given in this article, if laid out for any given coil design, will reveal a number of interesting points and provide a method for laying out coil designs to suit any particular case.

Table IV shows that to get a working voltage that is barely up to the 10 per cent limit for the half pitch it is necessary to use thirteen turns per coil. A further saving can be had on the short throws by making the windings more compact by reducing the air space between coils.

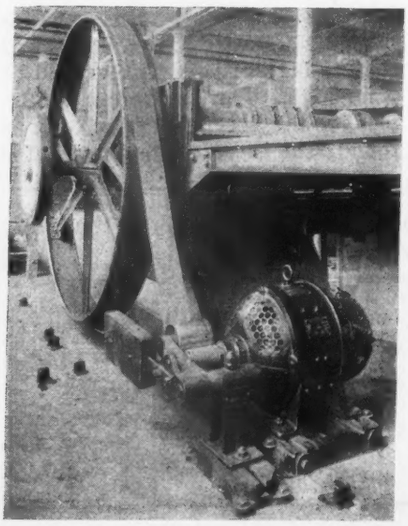
A further discussion on chorded pitch windings is contained in the following books: "Connecting Induction Motors," by A. M. Dudley, and "Connecting and Testing D.C. Machines," by Annett and Roe, both published by the McGraw-Hill Book Company, Inc., New York City.

Use of Belts on Motor Drives

(Continued from page 105)

The gravity idler pulley is generally supported on a hinged arm and is weighted to maintain a given tension on the slack side of the belt at all times. The idler pulley is so located that it increases the arc of contact of the belt on the smaller pulley, thereby increasing the traction at this limiting point. There are a number of commercial applications of this principle on the market, some of which are shown in the accompanying illustrations.

When gravity idlers are used there is no need for wide separation of pulleys and short belt centers may be used, which results in economy of floor space and a material reduction in the length of the belt. Also, higher pulley ratios may be used because the arc of contact on the smaller pulley is not affected, as on an ordinary belt drive, but may be increased considerably over 180 deg. With higher pulley ratios, higher speed motors may sometimes be used. The short-center drive compensates for belt stretch, within limits, and maintains a required belt tension without an excess, due to increasing the arc of contact, which decreases the necessary belt tension and consequently the pressure on the bearings.



Here is an example of the extremely high reduction ratio that is possible with short-center drives.

This drive on a machine in a box factory has a 30:1 pulley reduction. In addition, the motor is placed up close to and under the machine where it is out of the way. This is a Pulmax short-center drive installation.

Gravity idlers are not adapted for use where direction of rotation may be reversed. They have many commendable features, however, and their more general use appears justified. For example, vertical belt drives or drives operating at an angle greater than 45 deg. from the horizontal can be made to operate much more satisfactorily and with narrower belts and lower belt tensions by the use of such short-center drives. Endless belts should be used on these idler drives.

Another form of short-center modified belt drive is designated commercially as the Texrope (Allis-Chalmers Manufacturing Co.) drive. Grooved sheaves are connected by a number of V-belts of rubber fabric which are used in multiple to transmit the power. Some installations of this drive are shown in accompanying illustrations. This drive has a number of commendable features. It is simple and low in first cost. It was first developed for application to textile drives to eliminate slip, jerks, and lost motion resulting in excessive thread breakage. Its use has extended until it is now available for drives of over 1,000 hp. rating.

The maximum recommended speed reduction ratio for a Texrope drive is 7 or 8 to 1. Higher ratios are not recommended unless the centers are relatively long so that the arc of contact on the small sheave will be 120 deg. or more. The best belt speed is about 3,000 to 3,500 f.p.m., but speeds from 1,500 to 5,500 f.p.m. may be used. Several sizes of Texropes are used to cover the range of powers. The Texropes are endless loops and the center distances or sheave diameters must be suited to the belt lengths available.

Any number of Texropes may be operated in parallel to obtain the required capacity but excessive sheave or pulley width is not desirable because of flexural pull on an overhung motor shaft. Although no initial tension is required, the Texropes should be neither too loose nor too tight; hence a sliding base or rails under the motor are desirable.

Another article by Mr. Fox that will appear in an early issue will discuss the use of chains for connecting the motor to the driven machine or other load.

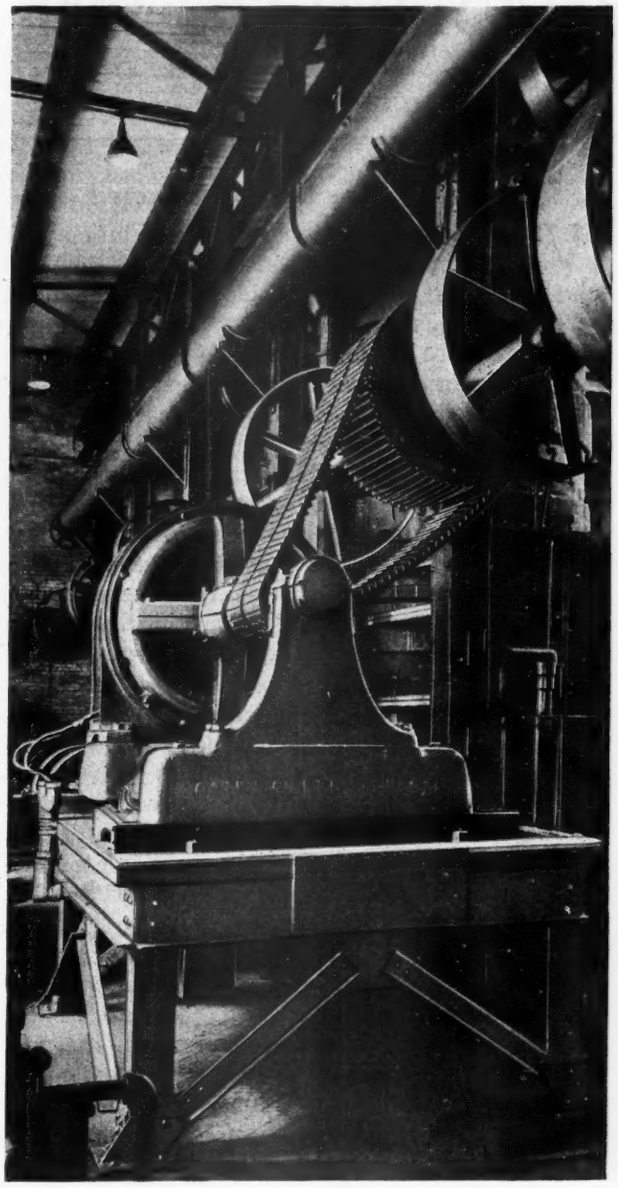
Construction Changes Under Difficulties

oftentimes tax the unusual ingenuity that an operating man must have

WHEN it comes to making changes in an existing plant, the big problem in almost every case is to find a way to get the required equipment in the place where it should go. It is a simple matter for a designing engineer to lay out a new floor of equipment with its required drives, and then, so to speak, build a building around this layout. In the case of later changes, however, most conditions are fixed—side walls cannot be moved, stairways cannot be torn out, steam, water and air piping is there to stay, and so on. It's simply up to the operating superintendent to get in between or around all of this and still get the results that are desired.

TAKE the case of a motor drive for instance, the moving and changing of which are always a part of a progressive operating program calling for speed changes, rearrangements of machines, and so forth, to suit new requirements or changes in the course that production follows through the plant. The production manager in working out a new movement of materials at machines, with almost no exceptions, says, "We'll place the machine here and Bill (the operating superintendent) will find a way to hook up the motor." And so Bill is called in to finish the job by main strength and awkwardness, plus all the ingenuity at his command. And his ingenuity might in many cases well be copied by others in making some new layouts.

THE accompanying photograph shows an example of such ingenuity under conditions that cannot be revealed in detail in a picture. For instance, the motor was on hand, and was of a design that is not easy to mount in close quarters. It could not be hung from the ceiling, first, because of the interferences and, second, because it would be hard to get a rigid support free from vibration. The only other solution was the giving up of the necessary floor space for a substantial platform constructed of such a height as to provide practical centers for the chain drive. This construction made it possible also to locate the motor drive at a point on the lineshaft so that it could be loaded on both sides of the driven sprocket, a condition that would not have been possible had the motor been suspended from the ceiling. While this was not the least expensive drive arrangement that could have been made, and probably would not have been used had the motor drive been installed when the lineshaft was put in, it has given good service and has justified the trouble it took to devise the scheme and work it out.



THIS particular installation I have referred to simply to bring out the kind of problems that are encountered in operating work, with nothing much said about them. I dare say that those who read this can point to several in their own plant which they have already forgotten. In that case, if you recall something particularly tough about a job, just take the time to draw a rough pencil sketch and send it to me with a description of the troubles that were encountered. I want not only to call this to the attention of others who may be interested, but to record the information in some appropriate way as evidence of the fact that the titles of superintendent, master mechanic, chief electrician, and the like, call for engineering ability of a high order and are worthy of compensation in keeping with the results secured.

Practical Pete

INDUSTRIAL ENGINEER
Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories
G. A. VAN BRUNT, *Editor*

Single-Phasing Can Be Stopped

WHEN a burned-out motor comes into a repair shop, whether this is operated by an industrial works or is an outside commercial shop, every possible check should be made to determine the actual cause of the burnout, particularly as to whether it might be due to single-phasing. If the trouble was single-phasing this fact can be determined unless the winding is completely roasted out.

In most cases single-phasing can be traced to carelessness on the part of some one; either the workman who installed the motor or starter, or the operator who replaces burned-out fuses. When a motor is running single-phase, that fact is made known by an unmistakable growling, and frequently more than one fuse will be blown. If two are blown and only one is located and replaced, the motor can be started again from the line side of the switch, which is connected ahead of the fuses, and when the switch is thrown over to the running position, the motor will still be operating single-phase.

Such carelessness in checking fuses is common, and in the case of single-phase operation of a motor is certain to be expensive. From a careful check on every burned-out motor winding before it is stripped off much can be learned that will save time and future repair costs. In case carelessness such as described cannot be eliminated, the only solution of single-phase burnouts is adequate protection of an automatic nature. This is not so expensive over a period of years as its first cost may appear, when considered alone.

Make Inspection Routines Cover Out-of-the-Way Equipment

MANY industrial executives have found that the best method of reducing operating interruptions is through organized inspection and maintenance procedure. The proper plan to follow is determined largely by the extent of the plant, the industry, and the operating service. In practically all cases daily inspections are desirable and most valuable.

Routines once established and occasionally checked up usually run along smoothly. Difficulty is sometimes encountered, however, in adapting the routine to the necessary changes in location or additions to the equipment. For example, one large Midwestern concern has divided its plant up into districts in each of which a route man makes the daily inspection and cleans, oils, and does the work that is necessary to maintain the equipment in operating condition.

One day a motor failed and an examination showed obvious lack of attention. In checking up to determine the responsibility for the neglect, it was found that the motor was installed in an out-of-the-way place, which was not within the territory served by any of the route men, and none of them had been notified to include the motor in his route. It had been operating without service for over a year before it became overheated and caught fire.

Some routine or method should be provided for notifying the route men about these unusual situations. Also, it is well for the head of the department or his assistant to check up every drive occasionally, to make sure that nothing is being missed. Furthermore, when a change or new installation is made, some individual other than the route men should be given the duty of making frequent inspections until it is assured that the equipment is operating satisfactorily.

Trends and Developments in Industry

FIGURES reported in the 1925 Census of Manufactures, which has been made biennially since 1919, reveal a number of interesting trends and developments in industry. For a number of years there has been a tendency for an increasingly large per cent of the total output of manufacturing industries to be produced by large companies, especially those whose annual value of product is over $1,000,000. This trend is in part revealed by the fact that the average number of wage earners per establishment increased from 38.94 workers in 1914, to 44.72 workers in 1923.

While these changes have been going on, there has also been a marked increase in the efficiency of production. For the same unit of production there were required, in 1923, 25 per cent less workers and 17 per cent less salaried officers and employees than in 1914. Part of this is due to the increased efficiency of management, and part to the increased use of power. In 1914 the average horsepower per establishment was 125.8 as compared with 168.5 in 1923; at the same time the horsepower per wage earner increased from 3.2 in 1914 to 3.7 in 1923.

Further evidence of concentration of industry is indicated by the returns for 156 separate industries. There was a decrease of 2.7 per cent in the number of establishments engaged in these industries in 1925, compared with the number that were manufacturing the same product in 1923. The number of wage earners also decreased by 1.9 per cent. Despite the decrease in both the number of establishments and the average number of wage earners

employed by them, the value of product increased 6.2 per cent.

The trend toward the further use of power in manufacturing processes is shown by an increase of 8.3 per cent in the primary power installed in these plants. In 1923 these same industries were employing an average of 122.7 hp. per plant. In 1925 they were using 140.2 hp. The horsepower per wage earner during the two-year period rose from 2.17 to 2.40.

Every plant manager can profitably bear in mind not only the fact that the horsepower per worker in American industries is rapidly increasing, but that this tendency is largely if not entirely responsible for our commercial supremacy and the development of our industries to their present status. The operator who does not take full advantage of every opportunity to replace hand labor with power-driven devices is putting his plant under a severe handicap in meeting competition.

Let Equipment Write Its History In Service Records

ANY operating executive who does not keep a complete service record for all important pieces of equipment is failing to take advantage of a most useful source of information. Intelligent selection and operation of equipment requires thorough knowledge of a number of important factors that comes largely as the result of experience. Among these factors are the reliability of the equipment, its suitability for the service conditions, amount of maintenance attention required, and cost of repairs over a reasonable period of time. This information can be used to advantage in a number of ways.

In the first place, unless there is a convenient method of checking up some of these points, undesirable and costly operating conditions may go unnoticed for a long time. Frequent inspections and careful repair work will go a long way towards reducing preventable breakdowns, but they will not necessarily improve operating conditions, or compensate entirely for defects in design or poor judgment in the selection of equipment.

Again, when a new item of equipment is to be selected, the information given on the service record of a similar item of the same make, or on the record of the device that is to be replaced, may prevent costly errors.

Every piece of equipment plainly tells us everything that we want to know about it, in terms of actual performance on the job. Its good points are easily seen by those who will take the trouble to watch it closely, and it reveals to us from time to time its weaknesses and troubles. Nevertheless, it remains for us to record the facts in such form that we can make use of the practical operating information that they contain.

Help-Yourself Oil Storage Is Costly

THE management of a large industrial plant paid well for the lesson which they recently learned in the handling and storage of lubricating and paint oils, and other liquids used in production and plant operation. All of these materials were stored on a "help-yourself" basis. No records were kept on the use of any of these materials, and so it was not known whether too much was used. The discovery of the waste was made from the outside.

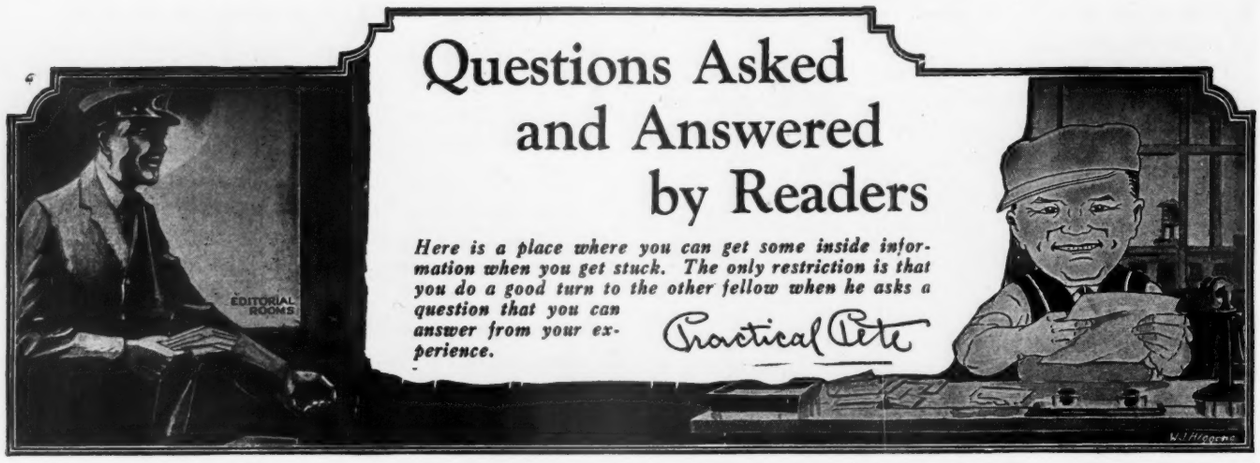
An enterprising laundry soap salesman set out to discover why the workmen's families did not buy much laundry soap from the village storekeeper. By means of a house-to-house canvass, he soon learned that many of the housewives were using a high-grade liquid soap which Bill, Jim, and Mike brought home from the factory. A request for an opportunity to bid on the plant's liquid soap requirements disclosed the quantity used. A simple problem of dividing this by the number of men employed showed that each employee was using an unusually large amount of liquid soap per month. To complete the story, there is now an increased market for soap in that town, and also a man in charge of the oil storage.

In the meantime, comparisons of the quantity of other liquids used against what should have been used showed that the consumption of several was far in excess of what it should be. This loss was immediately checked. Further investigations are now being made to determine the best plan for storage and handling of lubricants and other liquids.

Although there may be an inclination to criticize the dishonesty of the men, the loss could more justly be blamed upon the laxity of the management. When valuable materials are placed for each man to help himself and the men know that if a gallon or two is lost, or wasted, or spilled on the floor no one in charge seems to care about it, they can hardly be blamed for taking some.

Several salesmen had tried to interest this company in storage tanks and equipment for handling liquid materials, but the management always maintained that such equipment was not needed and that they were saving its cost and the expense of operating it. A close investigation, however, soon proved that the plant had, in other ways, paid for the necessary equipment many times over, and still did not have it.

Although such an excessive amount of waste is probably unusual in industrial plants, less striking examples are not uncommon, especially in connection with the storage and handling of oils and similar liquids. Plants which have installed tanks and other facilities for quantity storage of liquids will often find it profitable to investigate the handling and application of these after they are issued to the men.



Questions Asked and Answered by Readers

Here is a place where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience.

Practical Pete

QUESTIONS

Who Can Answer These?

Effect of Commutating Poles on Magnetic Field

I have noticed that some of our d.c. interpole machines are equipped with one commutating pole per pair of main poles, while others have one commutating pole for each main pole. In cases where one commutating pole is used per pair of main poles, is there any unbalancing in the magnetic field that will cause cross armature currents? Your opinion will be appreciated.
Seattle, Wash. W. M. P.

Testing Alignment of Right Angle Shafts

I wish some reader would help me out with some suggestions on a method of testing two shafts mounted at right angles and connected by bevel gears. The short shaft with the bevel gear consists of two 16-ft. sections of 2 7/16-in. shaft. The main 2 11/16-in. shaft is 60 ft. long. I am having trouble due to wear of the bevel gears and think that it is due to misalignment. What is the best way of checking this right angle? Also, how can I be sure that the two shafts are at the same level?
Cleveland, Ohio. E. H. G.

Cause of Short Life of Lamps

In our knitting department there are many belts, every other one being crossed. The wiring for the lighting system in this department is enclosed in conduit, which is grounded. I am using the No. 622 Holophane lighting unit, which is a glass reflector. Although I have used both 110- and 115-volt, A 23 and PS 25 lamps, respectively, on a circuit that indicates a constant voltage of 106 volts on a recording voltmeter, the lamps in these units last only about 100 hr. I shall appreciate any information that readers can give me as to why our lamps have such a short life, and how I can remedy this condition.
Newton, Mass. D. C. S.

Trouble With Squirrel-Cage Motor

On a dust collector in our cement plant we recently had occasion to replace a 5-hp. motor with a very old 10-hp. motor that had been standing in our store-room for some little time. We desired to speed up the fan of a dust collector and thought that this motor would do it inasmuch as it was rated at 850 r.p.m., 13 amp., 10 hp., 440 volts three-phase. After installing the motor and starting it, the resulting speed on the motor was only 250 r.p.m. while the current per phase was 8½ amp. After taking the belt off the motor and dust collector and letting the motor run idle the speed went up to 770 r.p.m. while the current decreased to 6 amp. per phase. I have never seen a squirrel-cage motor behave quite in this manner and cannot understand how the speed can drop as low as 250 r.p.m. without the load current going up to even normal rating. There was no sign of heating no matter how long the motor ran. It occurred to me that possibly some one had tampered with the coil connections so I opened up the motor and found the stator to be connected single circuit star. Can any reader suggest why this motor behaved in this manner?
Detroit, Mich. R. W. B.

How Should This Blower Be Driven?

I should like to have the advice of our readers on a drive problem. I have a blower with an 8-in. pulley which will be driven by a 720-r.p.m., 25-hp., three-phase, 25-cycle motor. To obtain the proper speed, if the blower is belted directly with motor, I will have to use a 26-in., cast-iron pulley on the motor. Will this make a satisfactory drive, or would it be better to use a jackshaft to secure the desired blower speed? In this case I could use a smaller motor pulley.
Toledo, Ohio. F. H.

Why Does This Commutator Wear Out of Round?

The life of a new commutator on one of our 3-hp., 230-volt, d.c., 1,150-r.p.m., style SK, Westinghouse motors is very short. This motor, which is belted to a suction fan, is located in a room where lead is melted and cast into bars. In an attempt to overcome our trouble we have tried different brushes, undercutting the commutator, and used good armatures from other machines, but about every three months the commutator becomes egg-shaped. Is it the acid or gas fumes, or something else that is causing the trouble? I shall be grateful for any information that readers can give me.
Chicago, Ill. F. J. C.

Checking Condition of Elevator Cables

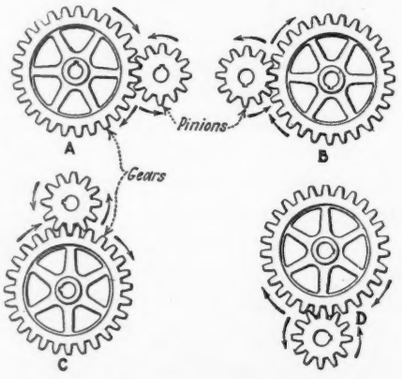
We are using the ordinary 6-19 cables on most of our elevators and I wish readers would give me some suggestions on inspecting them for condition. Can our maintenance men determine when these cables need to be replaced by counting the broken strands? If not, what other methods or tests can we employ that will safely determine this point? I shall appreciate any help from readers.
Auburn, N. Y. H. W. J.

ANSWERS

Received to Questions Asked

Location of Motor Pinion

Is there a preferred location of the motor pinion with respect to the driven gear? The accompanying diagram shows four different drive arrangements, one having the motor pinion on top of the driven gear, another with the pinion at the bottom, and others with the pinion on either side of the gear. The direction



of rotation of the gear and pinion is indicated by the arrows. Which of these locations is preferred from the standpoint of stress on the motor frame and on the foundation bolts, lubrication of gear and pinion, and ease of maintenance and inspection? Are they all equally good? I should like to have some of our readers discuss this question, and give me the benefit of an experience they may have had with such a problem.
Landgraff, W. Va. U. J. S.

REFERRING to U. J. S.'s question, a great deal of fine-haired theory could be spun on making the gear thrust balance the weight of the armature, arranging the thrust of the gear to push the motor down on the base instead of lifting it, and so on. However, I believe the most important consideration is to so locate the motor that it will have as solid a foundation as possible; that is, have the minimum of shimming or other construction work between it and the floor, and let the relative positions of the gears come where they will.

As most motor bearings are amply proportioned, they should withstand any load that the motor will subject them to in any direction, so long as the bearings are kept oiled, the rings kept free and the gearing receives proper lubrication.

It might at times be easier to inspect a pinion set above the gear, but the additional trouble of looking at it below the gear will be amply worth all it costs, as such a position lessens vibration; vibration is often the cause of wear and damage to both motor and gear drive.

It is impossible to stress too strongly the necessity of eliminating vibration, either for gear drives or other machinery, as vibration often pounds out the bearings, bearing bolts and grouting. Also, trouble is frequently caused in unexpected places by vibration, with the result that, under such conditions, you are always wondering what is going to break loose next.

Plant Engineer, H. D. FISHER.
New Haven Pulp & Board Co.,
New Haven, Conn.

ANSWERING U. J. S.'s question, the location of the motor pinion does not make much difference because the motor can often be located in any of the positions illustrated. The arrangement shown at *B* in his sketch is preferable, assuming, of course, that the motor is mounted with its feet down. With this arrangement all the pressure on the bearing is downward, and there is practically no strain on the foundation bolts, which is a desirable condition.

If the motor is mounted on the wall or ceiling, the same principle should be borne in mind; that is arrange the gearing so that the pressure will be exerted in the direction of the best support. GUY H. WINTERSTEEN.
Cleveland, Ohio.

REPLYING to U. J. S.'s question, one must sometimes be governed by local conditions and his own personal experience when locating motor pinions. For instance, there is little to recommend the arrangement shown in diagram *A* of this sketch, unless the gear and pinion were enclosed in an oil-tight gear case. In this instance only would it rank equal with arrangement *B*, and possibly at times it may even be better, for the reason that chips and other foreign matter would be less likely to be carried between the teeth, if they fell to bottom of the gear case. The arrangement at *A* might also have a tendency to lubricate the gear bearings better than in the case of the arrangement shown at *B*.

Generally, the arrangement at *B* is to be preferred over that at *A*, and over those shown at *C* and *D*, in the case of heavy drives. At *B* the accessibility of the motor frame will allow the gears to be realigned for wear without shimming. With the rotation as shown at *B*, it will be impossible for chips, tools, or other foreign objects to fall and become jammed between the pinion and the gear, in which case the gear would be ruined and the shaft would probably be damaged. If the gear's lower portion is partly in a concrete pit, it is not advisable to have the pit conform to the shape of the gear but rather make the pit rectangular, and in this way eliminate any chance of small objects accumulating in a small clearance space.

The distance between the gear and the bottom of the pit should be four times greater than the maximum openings at the sides. Such a pit will prevent tools and other material from finding their way into a position that might allow them to become wedged under the gears. A steel trap door should be left near the center of the pit, so that it can be cleaned out occasionally. The principal disadvantage of this arrangement is that more floor space is required when a pit is provided.

An arrangement similar to that at diagram *C* is limited to light or medium drives, under usual conditions. The advantage of this arrangement is that the gears and bearings are easy to inspect, the strain on the motor frame is less than with any of the drives shown at *A*, *B*, *C*, and *D*, the motor is kept away from grease and oil drippings, and the lubricant in the motor bearings is not likely to become polluted by gear case contents, as might be the case in *D*, if it were fully enclosed. The motor cannot only be shimmed up, but shims can be removed to allow for wear on open or semi-open drives. In addition the motor can easily be removed for repairs. Little floor space is required and the gears can be enclosed and kept well lubricated. The principal disadvantage of the arrangement at *C* is that with medium heavy drives, especially, a substantial motor support of reinforced concrete is usually required, constructed in a pyramid shape, the bottom of which would be some distance under the floor. In the case of larger motors, the height at which it must be mounted above the floor causes excessive floor vibration in some cases, unless the driven shaft is in a pit under the floor level.

The nature of the work to be performed is of major importance when considering the arrangement shown at *D*. On many types of machines the motor must be below the work or to one side of it, because of possible oil leaks. On shears and similar machines, this arrangement is used to provide a more convenient location with respect to the work table. There are some disadvantages with arrangement *D*, however, for when the motor is placed under the driven shaft, it is harder to make inspections and to clean the motor as it usually needs cleaning more often, due to grease, oil, chips and other foreign matter that may fall from above. If the motor is placed a little to one side of the large gear, the drive is easier to inspect but occupies more floor space and is likely to become a stumbling block.

Without doubt, the position of the motor shown at *D* will result in slightly increased bearing wear as compared with the other arrangements, as well as pollution of motor bearing lubricant, if the gears run in oil or grease in a gear case. A. FIESS.
Tampa, Fla.

Testing Fuses to Prevent Motors Running Single-Phase

We have a large number of three-phase induction motors that are protected by individual fuses placed near each motor. Also, the different branch circuits feeding several motors are protected by fuses. To insure that the motors do not operate single-phase, frequent tests are made of the fuses. Is it sufficient to test the fuses by temporarily connecting a lamp of suitable voltage across the ends of each individual fuse? Will a lamp test across the phase wires ahead of or after the fuses give a positive indication? Will connecting the lamp ahead of one fuse and behind the adjacent fuse give a reliable indication? I should like to have some of the readers discuss these questions for me and point out which is the best method to use for testing under the conditions described and also tell how to interpret the different indications obtained from the lamp.
Newark, N. J. W. S.

ANSWERING W. S.'s question, he could use a voltmeter, and if any of the phases are below normal voltage, he can rest assured that there is a fuse blown. In some cases a fuse at the main line (service entrance) switch may have blown and with several motors running a small motor can be started without detecting the blown fuse; so if a lamp is used at this time to test the fuses the slight drop in voltage would not be noticed.

In case that only a lamp is available for testing and it is suspected that a main fuse has blown, try to start the largest motor on the job, and if it refuses to start, the chances are that a fuse has blown. In order to locate the faulty fuse start at the entrance switch after opening it, so as to disconnect all of the load, and test the fuses on the various circuits in the order that you come to them until the faulty fuse is located. While testing the fuses be certain that the motors are shut down so that no current can circulate from one phase to another. H. J. ACHEE.
District Line Supt.,
Southwest Light & Power Co.
Elk City, Okla.

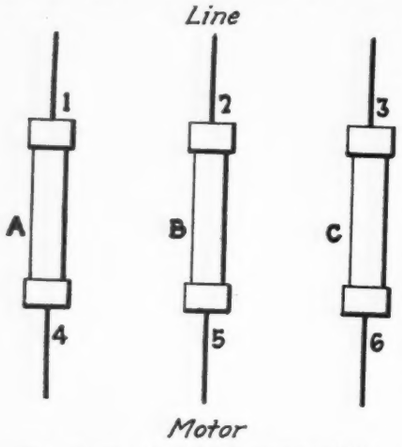
I WILL answer W. S.'s question by telling how 4,041, three-phase, 220-volt loom motors, each with its own switch and cut-out, are taken care of.

We have found that test lamps connected on the load side of the fuses, when the motor is stopped, give the best results. If the motor is running with one fuse gone, the dim light across the open phase is often mistaken for the full brilliancy of the lamp, but if the fuses are tested when the motor is stopped, then a full *out* or *on* of the lights cannot be mistaken.

In testing branch circuits which supply several motors one must be certain all of the motors are shut down before beginning the lamp test because if a motor is running while testing the fuses, the transformer action of the motor will light the lamp to about half brilliancy on the open phase.

By connecting one of the lamp terminals to the line side of one fuse and the other terminal to the motor side of another fuse it is possible to tell which one of a set of fuses is blown when the motor is stopped, for a full light then positively indicates which fuse is faulty. An operator can often detect faulty fuses or an open circuit in the supply line by the way a large motor starts.
Marblehead, Mass. HAROLD H. STEELE.

IN ORDER to obtain specific information in answer to W.S.'s question, I ran a test with a three-phase, 5-hp., 220-volt, 60-cycle induction motor. The terminals of the fuses will be referred to as *1*, *2*, and *3* respectively on the line side of the fuses and as *4*, *5*, and *6* on the motor side.



This shows the points across which the voltage was measured to detect a blown fuse in a three-phase circuit supplying a motor.

When the motor was not running, the line voltage was 220.5 volts between points *1* and *2;* 221.5 volts between points *2* and *3;* and, 220 volts between points *1* and *3*. While the motor was running, the line voltage was 220 volts between points *1* and *2;* 220.5 volts between *2* and *3;* and, 219.8 volts between *1* and *3*. After removing one fuse from phase *A*, the voltage was 196.5 between points *4* and *5*, 218 volts between *5* and *6*, and, 194-198 (variable) volts between *4* and *6*. The voltage to ground while the motor was running or idle was 119 volts on all phases. After the fuse was removed from phase *A*, the voltage between point *4* and ground was 89 volts, between point *5* and ground, 108 volts, and between point *6* and ground, 102 volts. The variation in voltage between ground and points *4*, *5*, and *6* may have been due to using a temporary ground. The voltage between points *1* and *4*, *2* and *5*, and *3* and *6* was zero until one fuse was removed from phase *A*, thus causing a voltage drop of 22 volts between points *1* and *4*. A test lamp placed across these two points burned at approximately one-quarter brilliancy and drew 192 mil.-amp. The normal current of this lamp at full brilliancy is 442 mil.-amp. The lamp used was a 115-volt, 50-watt, mill-type Westinghouse lamp. A carbon lamp was then substituted for the tungsten filament lamp, its rating being 16 cp. at 115 volts. When this lamp was used, the filament became quite red, but not as brilliant as the tungsten lamp. This carbon lamp drew 120 mil.-amp., while its normal current was found to be 622 mil.-amp. on a 116-volt lighting circuit.

I believe that 15 volts is sufficient to force enough current through a lamp filament to get at least a test indication, particularly if a tungsten or a tantalum light were used, for these two lamps show only a small resistance when cold, but a high resistance when heated. The resistance of the carbon filament lamp is higher when cold than when hot.

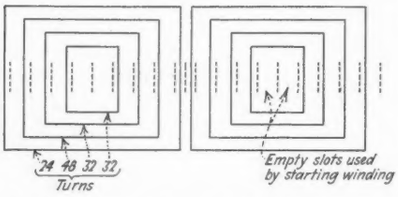
My test was conducted on a motor running practically without load, and as the counter-electromotive force drops as the load increases, the difference between the two voltages increases; consequently, an increase of load on the motor would tend to increase the brilliancy of the test lamp while spanning the blown fuse.

Personally, I much prefer a thermal cut-out, of which there are a number of good makes on the market, as a means of protecting a motor against single-phase operation. I feel that such devices are a profitable investment for those who are having trouble with their three-phase motors running single phase.

E. J. MORRISSEY.
Chief Electrician,
Western United Gas & Electric Co.,
Aurora, Ill.

Method of Determining Chord Factor

I shall appreciate receiving any information from readers concerning satisfactory methods of finding the chord factor for the following winding. The winding is on the stator of a ½-hp., 110-volt, 60-cycle, single-phase induction motor. The stator has 36 slots and four poles and is arranged with a starting winding. The main winding is connected as a whole coil, concentric, as is shown in the accompanying diagram, which shows two pole groups.



Milwaukee, Wis. J. M.

ANSWERING J. M., finding the chord factor of a single-phase motor is quite similar to finding the chord factor of a three-phase motor winding.

Chord factor is defined as the sine of one-half the angle spanned by the coil. In the single-phase winding each pole has several coils which span a different number of slots and for that reason each coil will have a different chord factor. In the three-phase motor, each coil spans the same number of slots and consequently each coil will have the same chord factor.

To see that the above is true, it is necessary to remember that the coil in the center of the pole will not be as effective as if it were in the position of the outside coil. The chord factor multiplied by the actual number of turns will give the number of turns which would produce the same results if the winding were not chorded. The above statement applies only for the turns in series.

In a four-pole motor each coil must span 90 space degrees. Space degrees cannot be used for determining the chord factor because only in a two-pole machine is the number of space degrees equal to the electrical degrees. Each pole will then have 180 electrical degrees. The sine of one-half of 180 deg. or 90 deg. is unity. Also, the chord factor of the outside coil of each pole is unity.

The chord factor has already been found for the outside coil. The second coil or the one with 48 turns will be considered next. Since the motor has 36 slots and four poles, each pole will be the equivalent of 36 ÷ 4, or 9 slots. These nine slots will be equal to 180 electrical degrees. Each slot will be removed 20 deg. from the one next to it. The coil under consideration then will span 7 x 20 or 140 electrical degrees. The chord factor will be the sine of 140 ÷ 2 = 70 deg., or 0.94.

These relations are shown in the accompanying table. The last column gives the product of the actual number of turns times the chord factor. It is interesting to note that the inside coil has 32 turns and yet has the effect of only 16, if the 16 were wound full pitch.

Since the other three poles are identical with the one that was considered, it is not necessary to make the calculations over again. The figures at the bottom of the last two columns show the effect of chording.

CHAS. F. CAMERON
Rock Springs, Wyoming.

THE method of finding the chord factor of J. M.'s motor involves considerable figuring, first, because the slots do not have the same number of wires in them, and, second, because some coils are half-coils and some are whole coils.

The motor has four poles and 36 slots; so one pole contains nine slots. Since two poles represent 360 electrical degrees and 2 x 9 or 18 slots represent 360 electrical degrees, one slot equals 360 ÷ 18, or 20 electrical degrees.

To find the factor for part 1 use the formula given in Dudley's, "Connecting Induction Motors." The chord factor is the sine of one-half the angle in electrical degrees that the coil spans, or sine of 60 deg. ÷ 2 = 30 deg. A table gives the sine of a 30-deg. angle

Chord Factor Data for Single-Phase Motor

No. or Coil	Coil Spans	Coil Span ÷2	Chord Factor or Sine	Number of Turns	Turns × Chord Factor
1	180	90	1.0	24	24.0
2	140	70	0.940	48	45.12
3	100	50	0.766	32	24.51
4	60	30	0.5	32	16.0

as 0.50. Therefore, part 1 is only 50 per cent as effective as it would be if it were full pitch. So credit part 1 with 50 per cent of 32 turns, or 16 turns.

Part 2 spans five slots or 5 × 20 = 100 electrical degrees. Proceeding as with the calculations for part 1, the table gives the sine of one-half of a 100-deg. angle as 0.766. Then part 2 can be credited with 0.766 × 32, or 24.5 turns at full pitch.

With part 3, proceed as with parts 1 and 2. The angle spanned in electrical degrees is 140. The sine of half of 140 deg. is 0.9397, thus crediting part 3 with 0.9397 × 48, or 45 turns at full pitch.

Part 4 is already full pitch; so this part can be credited for the full number of turns, which is 24. Adding the credits, 16 + 24.5 + 45 + 24 = 109.5. The actual turns are 32 + 32 + 48 + 24, or 136.

The chord factor sought is 109.5 ÷ 136 = 0.805. The distribution factor will be about 0.87 and the winding factor 0.71. CLAUDE D. MARTIN.
Fort Dodge, Iowa.

IN ANSWER to question asked by J.M., I would say that the chord factor, K_2, is the sine of one-half the angle spanned by a coil, in electrical degrees. In case the coils do not all span the same angle, K_2 may be used to represent the sine of one-half the average electrical degree spanned.

In the present case, one pole spans 180 deg. Inasmuch as there are 9 slots per pole, 180 deg. ÷ 9 = 20 deg. per slot. The largest coil spans 180 deg., the second coil 140 deg., the third 100 deg., and the fourth coil spans 60 deg., or an average span of 120 degrees. Then K_2 = sin (120 ÷ 2) = 0.866. Generally, this method of finding the value of K_2 is close enough for most practical purposes.
Murphy, Idaho. ALEX BRENNER, JR.

ANSWERING J. M., I have used with good results the following methods for determining the chord factor.

Chord factor is determined by finding the sine of one-half the angle in electrical degrees which the coil spans. The number of slots divided by the number of poles will equal the number of slots per pole which amount represents 180 electrical degrees. Then, 180 deg. divided by the number of slots per pole will give the number of degrees per slot. The number of degrees per slot multiplied by the number of slots spanned will give the number of degrees spanned. This result divided by two will be the number of degrees, the sine of which is the chord factor and must be found by consulting a table of trigonometric functions.

In J. M's case the pitch will be the average pitch. The spans are 1-10, 2-9, 3-8, and 4-7. Now, since nine slots are spanned in the 1-10 span, seven in the 2-9 span, five in the 3-8 span, and three in the 4-7 span, it is obvious that the average of nine, seven, five, and three equals six. Therefore, the average pitch is 6/9 or 66.6 per cent.

Applying the above formula to the problem: 36 (slots) ÷ 4 (poles) = 9, Now 180 deg. ÷ 9 = 20 deg. per slot; 20 deg. × 6, the average span, equals 120 deg. 120 ÷ 2 = 60 deg. The sine of 60 deg. = 0.866, which is the pitch constant or chord factor.

After noting a variety of motors, I have plotted a curve from which a few constants have been taken, as shown in the accompanying table, that will eliminate the above calculations.

Slot Pitches and Equivalent Chord Factors

Slot Pitch	Per Cent Pitch	Chord Factor (K_2)
6/6	100	1.00
5/6	83.3	.966
4/5	80	.951
3/4	75	.924
2/3	66.6	.866
1/2	50	.707

It will be noted from this table that 6/9 is the average pitch and 6/9 equals 66.6 per cent, which pitch indicates a chord factor of 0.866. H. KAELIN.
Kaelin & Beer Electric Co.,
Los Angeles, Calif.

Will This Generator Operate Satisfactorily at Increased Speed?

We have a Westinghouse, Type C, 50-hp., alternating-current motor having a full-load speed of 850 r.p.m., which we plan to use in driving a General Electric direct-current 55-hp., 725-r.p.m. 110-volt generator. We would like to couple these two units directly together instead of making a belt-driven unit. This would necessitate running the 725-r.p.m. generator at a speed of 850 r.p.m., or an increase of 17 per cent in speed. I should like to learn from readers whether or not this generator will operate satisfactorily at this speed, and also whether the increased voltage delivered by the generator can be reduced in any way so as to obtain the original voltage generated at 725 r.p.m.
Hartford, Conn. H. V. D.

IN REPLY to H. V. D., if the armature is securely banded so that the extra centrifugal force exerted on it will not cause the coils to raise, the higher driving speed will cause no trouble.

The additional voltage can be easily taken car of by using a rheostat with a higher ohmic resistance. The additional voltage would require a rheostat of approximately twice the ohmic resistance that is needed with the lower voltage, for the fields on a generator are designed for 20 per cent less resistance than on a motor of the same voltage rating. This is done to allow for regulation of the voltage on the generator.

If there are available two rheostats of the same capacity, connect the two rheostats in series with the shunt fields; then cut in all the resistance in one rheostat and do the regulating with the other one. NICHOLAS J. WEISS.
West New York, N. J.

IN REPLY to the inquiry by H. V. D., I would say that if these machines are connected direct, the generator will give approximately 140 volts.

If H. V. D. inserts the proper amount of resistance in the shunt field circuit of the generator in addition to the field rheostat, he will be able to get the proper voltage regulation, providing the commutation is good. If it is not, the arrangement he proposes is not practicable because the generator will always be a source of trouble due to poor commutation caused by the weakening of the shunt field on account of the resistance required to get the desired voltage regulation. This is about the only way that the original voltage can be maintained on this machine unless it is rewound to suit the change in speed. JOHN COAN.
Chief Electrician,
Rocky Mountain Fuel Co.,
Lafayette, Colo.

REPLYING to H. V. D.'s inquiry, the increase in voltage due to the increase in speed can be reduced by cutting in a little more resistance with the generator field rheostat.

In case this machine, when operating at 725 r.p.m., requires that the rheostat be two-thirds cut out, the rheostat should be sufficient to take care of the greater field strength caused by the higher speed, but if only a few steps of the rheostat are cut out, the voltage will be too high while running the generator at 850 r.p.m., for the rheostat would then have insufficient resistance.

To overcome the lack of resistance, set the rheostat about half way in and insert extra resistance in series with the rheostat until the desired voltage is obtained. This method will provide an excellent adjustment on the rheostat to take care of the variations in the load.

The increase in speed should not have any effect on the machine, as the design is ample to take care of the additional centrifugal force in the armature.

In case H. V. D. has around the plant an additional rheostat of about the same size and design as the one used with the generator, I would advise installing the two in series, and then practically any adjustments can be made to take care of the higher voltage caused by the change in speed.

I had an experience of this kind several years ago, where we increased the speed 25 per cent, and operation was perfectly satisfactory. We installed another rheostat of the same size and capacity in series with the old one and were able to regulate the voltage of the machine at the new speed just as easily as was possible at the former speed. LEE F. DANN.
Chief Electrician,
Donnacona Paper Co., Ltd.,
Donnacona, Que., Can.

THE answer to H. V. D.'s question can best be given only by the manufacturer's design department.

It is usually quite safe to operate a motor or generator at 10 per cent above its normal rated speed. On this assumption it would be safe to operate the generator under consideration at about 800 r.p.m., but an increase to 850 r.p.m. would be about 17 per cent above normal, and although the generator would undoubtedly stand this increase for short periods, continuous operation

at this speed should not be carried out without consulting the manufacturer of the generator, for certain designs have definite operating limits.

Just exactly how the increase in speed will affect the voltage is not certain without knowing more about the design of the generator. In general, the voltage will increase in direct proportion to the speed for a certain fixed condition, and it is quite possible that the present field rheostat will take care of the increase in voltage. In any event, additional resistance can be added in the field circuit either as a fixed unit or through a change in the field rheostat, as can be readily determined by trial.

C. OTTO VON DANNENBERG.

Electrical Division,
General Engineering & Management Corp.,
New York, N. Y.

Trouble with Storage Battery Charging Generator

We are having considerable trouble due to the reversal of polarity on a 50-kw., 120-volt, interpole generator which is used to charge storage batteries on vehicles. The machines were tested for grounds by means of a Megger and a heavy leakage to ground through the acid-soaked benches in the battery charging department was discovered. Having remedied this, the generator was started and immediately the voltmeter read backwards with no load on the machine. We checked the leads from the machine, but they were of such size and so taped together that it would be impossible to reverse them by mistake. We tried to re-excite the field, but could not; so the leads were reconnected so as to reverse them at the generator and not disturb anything at the switchboard. The generator worked satisfactorily for about three days, when the polarity again reversed itself. We reversed the generator leads to their original position and since then the machine has been operating satisfactorily. I do not know what caused this reversal of polarity and should like to have readers give me their suggestions.

Sacramento, Calif. J. T.

IN ANSWER to J. T., the cause of the trouble could be due to the compound winding being in opposition to the shunt field and thus overcoming the shunt field when it is weakened by the field rheostat. If this is the case, reversing the compound field leads will correct the trouble.

Then again, if this generator is working in parallel with other machines that are compound wound, there should be an equalizer connection, otherwise these other generators many cause J. T.'s generator to reverse its polarity.

District Line Supt. H. J. ACHEE.
Southwest Light & Pow.r Co.,
Elk City, Okla.

Lubricating Ball and Roller Bearings

I wisk to know how thin an oil can be satisfactorily used to lubricate ball and roller bearings used in motors. Do readers prefer the use of grease for these applications and if so, why? What are the desirable characteristics of oils and greases that are intended for use on the roller bearings and ball bearings used in motors?

Youngstown, Ohio. E. L.

IN CONNECTION with the question asked by E. L., there seems to be quite a number of plants that are now testing out various methods of lubrication. My personal opinion is that for general purpose work it is better to use grease for lubrication. The grease should ordinarily be of a consistency slightly harder than vaseline, so that it will maintain its body and not run off the metal surfaces too freely, and not become solid or dry.

It seems to me that the theory of correct lubrication involves the use of a thin film of lubricant between friction-developing surfaces, and some people claim that under favorable conditions an almost imperceptible film of lubricant is sufficient.

The use of oil provides this film during the period of motion, but after motion has been stopped for some time, the oil falls to the bottom of the oil well and leaves dry bearing surfaces. It is conceded that some oil will remain as a thin film on the shaft, but the amount that remains is usually very small and often insufficient to prevent rusting.

It is generally difficult to adopt an ideal lubricant for all the motors in a plant because a motor may be in a dry or moist location, surrounded by air that is clean or dirty, designed with large or small bearing surfaces, and operate with its bearings cold, at normal temperature, or hot. I would recommend that several different grades of lubricants, my preference is grease, be tried out on the various jobs until each machine has had the proper kind of lubricant selected for it.

NATHANIEL W. BLANCHARD.

Inwood, L. I.

IN ANSWER to E. L.'s question, and commenting on a previous answer to this question, I wish to advise that the makers of anti-friction bearings especially discourage the use of graphite as it is considered very injurious to ball and roller bearings.

As a rule, a high-grade mineral grease of light or medium consistency has been found most satisfactory for general-purpose electric motors using ball bearings. Such a grease will not leak past the average seal and will prevent the entrance of dirt into the bearings. Very high speed motors require different treatment and usually employ a light oil fed in small quantities.

H. W. HOLDSWORTH.

Engineering Dept.,
The New Department Mfg. Co.,
Bristol, Conn.

IN REGARD to the question asked by E. L., a mineral oil with a viscosity of 100-200 sec. Saybolt at 100 deg. F. should be used for bearings on small high-speed motors. With roller bearings it is best to use a mineral oil up to 750 sec. Saybolt at 100 deg. F.

A straight petroleum grease should be used in dirty locations for it seals the bearings against dust, dirt and moisture, and it is easier to retain grease than oil in a non-oil-tight bearing. However, grease should not be used for roller bearings revolving over 1,200 r.p.m.

The oil used should not contain any compound of animal or vegetable oil, should be neither acid nor alkali, and should not readily absorb moisture or saponify.

For ball bearings in clean locations, use oil, but in dusty or dirty locations, use light grease, and for roller bearings use a heavy-bodied mineral oil or a medium grease. W. E. WARNER.

Shefford, Bedfordshire, England.

Trouble from Cable Overheating

When connecting up a turbo-generator rated at 480 volts, three phase, 60 cycles, 3,000 amp., I used five 1,000,000-circ.mil, rubber-covered cables in parallel. According to the wire table each cable should carry 650 amp.; therefore, the six cables in parallel should carry a total of 3,900 amp. The total of 18 cables for the three phases run in six conduits, each conduit carrying three cables, one from each phase. With this arrangement the cables heated and I fould it necessary to add a seventh cable to each phase. This should give a total carrying capacity of 4,550 amp. which is 50 per cent more than the rating of the turbo-generator, 3,000 amp. With the seven cables operating in parallel on each phase there is no heating and the cables carry satisfactorily an average load of 3,000 amp. with peaks running somewhat over 3,500 amp. Can any reader suggest causes why the first installation of cables should overheat? Could it be due to inductive effects? If so, how could I go about correcting this trouble?

Bellingham, Wash. E. M. D.

THE trouble experienced by E.M.D. is probably due to a great extent to the lack of suitable radiating surface, which was caused by too great a concentration of the cables. Without having a layout of the conduit arrangement, it is impossible to tell just how close the cables are run.

A rating of 650 amp. for a 1,000,000-circ.mil cable applies strictly to a single cable. The allowable carrying capacity must be modified when three cables are carried in one conduit and when there are adjacent conduits which would further tend to reduce the heat radiation. Problems of this nature are often encountered in underground conduit work and they require special treatment and recommendations, depending upon the arrangement of the cables, as well as the average temperature surrounding the conduits.

For instance, published data by a cable manufacturer states that with a cable capacity of 100 per cent at 75 deg. F., the capacity of the cable will be reduced practically 50 per cent when the temperature is 130 deg. F. Assuming that a single conductor cable has a 100 per cent capacity, a three-conductor cable will have the conductor capacity reduced 75 per cent. In the present case, using three single conductors in a conduit will probably reduce the capacity of each conductor to approximately 85 per cent of its normal capacity, or 550 amp., although this value will be further reduced by the concentration of 21 cables in a small area, thus interfering with the radiation so that it is practically impossible to tell in this case, except by actual experience, just what size cables to use.

Certain published data state that where more than two cables are run in adjacent ducts the capacity per conductor is reduced 54 per cent when there are 12 cables. While this statement applies to underground construction, it indicates clearly the reduction in a conductor's capacity due to limited radiation. Referring specifically to this case under consideration, loads requiring the use of more than one 1,000,000-circ.mil cable per leg should, if possible, be carried by means of copper bars, when it is at all possible to do so. Also, the conductor should be installed bare, for this low voltage, if the conditions permit. The advantage of a bar conductor over round cable

is obvious when it is realized that a bar 4 in. by ¼ in. has a perimeter of 8½ in., while a round cable of equivalent circular mil capacity, say 1,250,000 circ.mils, has a circumference of only 4.03 in.; in other words the bar has twice the radiating surface per foot of length and hence has considerably greater carrying capacity. A manufacturing concern that has investigated the transmission of heavy alternating currents, recommends that for a 60-cycle, 3,000-amp. current, three 4-in. x ¼-in. bar conductors be used and arranged with the two in the top row ¼ in. apart, and the third bar 2 in. below the other two. It is obvious, however, that without knowing the exact operating conditions referred to by E.M.D. only a general answer can be given.

C. OTTO VON DANNENBERG.

Electrical Division,
General Engineering & Management Corp.,
New York, N. Y.

IN REPLY to E.M.D., I assume that he was using six cables of 1,000,000-circ.mil area and increased the number of cables per phase from six to seven as a means of overcoming the excessive heating of the cables, which would likely cause serious trouble.

I do not see any reason to believe that the heating was due to induction, as the arrangement of the cables would preclude this possibility, but feel that it was most likely due to the carrying of so many large cables in one conduit, with no way of dissipating the heat fast enough to keep the cable temperatures down to normal.

It does seem that cables, grouped in a manner to prevent induction, should carry the required current, if due allowance were made to take care of the radiation, or if the cables were connected directly to the buses without conduit.

The radiation of heat from cables becomes a serious consideration with cables of heavy current capacity. As an illustration of this point, experiments show that the carrying capacity of cables so grouped is from 4 to 25 per cent less than the single conductor capacities when amply ventilated. The corner cables in a square conduit will carry the most current for same temperature rise as other cables in the group.

I would blame the trouble with the cables on the small amount of radiation, although there are a number of other considerations of less consequence that enter into the problem and must be given proper attention.

E. J. MORRISSEY.

Chief Electrician,
Western United Gas & Electric Co.,
Aurora, Ill.

REPLYING to E.M.D., although it is true that the wire table gives 650 amp. as the carrying capacity of a 1,000,000-circ.mil cable, this applies to only one cable. When several cables are used in parallel, their ratings are much different on account of induction, cooling space, location and method of installation, as open wiring, or arrangement in conduit, or fiber and tile ducts, etc.

E.M.D. says that there were originally six conduits, three cables per conduit, six cables per phase in the first installation, and it was found necessary to add another cable to each phase, making a total of seven cables per phase.

The layout of the conduit may be considered fair, if there is a chance for cooling air to enter the ends of the conduit or to come in contact with the conduit elsewhere in the run. The size of the conduit installed has not been given; so I cannot determine the cooling space inside the conduit. The current densities in cables, run as these have been, are unequal and it is doubtful if the cables could be rated at much over 450 amp. each, due to several causes.

Putting all three phases in each conduit is the correct arrangement, and if the cables were run any other way, they would no doubt operate very hot and all metering would be inaccurate. Cables in conduit runs give practically the same current-carrying conditions as busbars on a bus structure. For example, one ¼-in. x 4-in. busbar carries 1,200 amp. safely, while two ¼-in. x 4-in. busbars in parallel carry 2,200 amp., or less than double the capacity of one bar. When four ¼-in. x 4-in. busbars are placed in parallel with a ¾-in. spacing between bars and standard spacing between phases and ground, the capacity is limited to about 3,300 amp., unless forced ventilation is employed.

When conditions permit busbars may be transposed, thus gaining considerable capacity, but this is seldom done due to the complicated bending which would be encountered. After two or more cables or buses are employed in parallel, the ampere-capacity curve drops off very sharply and when as many as 12 cables are used in parallel the total rating is only 50 per cent of the sum of their individual ratings, as indicated in wire tables.

If E.M.D. cares to make a change in the cables, it would be advisable to have a smaller number of conduits, and cables of a larger size. One method that could be used would be to install fiber ducts or tile ducts and use lead-covered cable. If lead-covered cable is used, do not use single-conductor cables, but use three-conductor cables.

These will then be very large and difficult to handle, but once installed correctly the trouble is remedied and can be forgotten as far as the cable is concerned. In the event that lead cables are used, suitable non-magnetic cable potheads will be required. I might suggest the use of a three-conductor, 1,500,000-circ.mil lead-covered, paper-insulated cable. In this case it would be necessary to use four of these cables in order to obtain the necessary carrying capacity.

Cables laid in fiber or tile duct systems are rated in the following manner: Assuming that the capacity of one of the above-mentioned cables installed in a duct system is 898 amp., if two cables are used together in the system the capacity of each cable will be reduced to 90 per cent, or the total rating of the two cables will be reduced 10 per cent.

When four cables are installed, as would be necessary in this case, the capacity of the four cables would be approximately 75 per cent of the total rating of each cable when used singly, or $898 \times 4 \times 0.75 = 2{,}694$. These figures are based on cables operating at only 65 deg. F., which is cool. These cables at a temperature of 95 to 100 deg. F. will carry from 3,200 to 3,400 amp. safely, and 100 deg. F. is not too warm. If the expense of lead cable is not warranted, it would be advisable to install two 6-in. conduits. In these two conduits install two 2,000,000-circ.mil r.c. cables per leg, making a total of six 2,000,000-circ.mil cables, three cables in each conduit, with the three phases represented in each conduit. Two 2,000,000-circ.mil cables will easily carry 3,000 amp. and 3,500 amp. can be carried for peak loads of only an hour or so.

If E.M.D. had given the length of the cable runs and also a sketch showing their location, it might have been possible to rearrange the cables in such a manner as to further increase their capacity and permit the use of the present cables, but with the information furnished, I would recommend either one of the two above-mentioned layouts, in preference to trying to use the present cables in some other way. Cable installations taking care of heavy loads present a proposition that is difficult to handle, besides requiring much experience and an exact knowledge of each installation regarding the location of the cables and other important factors.

I would like to hear from him personally or through the columns of INDUSTRIAL ENGINEER concerning the methods used in the final installation and the results obtained.

LEE F. DANN.

Chief Electrician,
Donnacona Paper Co., Ltd.
Donnacona, Que., Can.

Soldering Springs in Ammeters

Will some reader kindly tell me the best method of procedure in soldering the springs in electrical instruments of delicate construction, such as ammeters, voltmeters, wattmeters, and the like? These springs are usually made of phosphor bronze, although some other materials are sometimes used. I should like to know what mixture of solder should be used and also what kind of flux is best adapted to the work. Any other hints that readers may give me in regard to the method of soldering will be very much appreciated.

L. A.

New York, N. Y.

REPLYING to L. A.'s inquiry phosphor-bronze springs can be successfuly soldered, with the ordinary jewelers' silver solder and flux, but almost invariably the soldering will affect the temper of the spring to such an extent that afterwards it is impossible to recalibrate the instrument with any degree of accuracy. The method of soldering these springs employed by the manufacturers seems to be well guarded; so I have found it cheaper and more satisfactory to return such instruments to their maker when repairs on them are necessary. Nothing is to be gained, and much may be lost, by trying to do a job for which the necessary experience or facilities are lacking.

G. H. WINTERSTEEN.

Cleveland, Ohio.

Difference Between Star and Delta-Connected Motor Windings

Can some reader tell me if there is any difference in the starting current, torque, power factor, and efficiency of a star-connected motor winding as compared to a delta-connected winding. In each case the motors under consideration are of the same make, horsepower, and number of coils. Why are some motors star-connected while others are delta-connected? Does either form of connection have advantages over the other? I shall greatly appreciate any information that readers may give me on this subject.
Lethbridge, Alberta, Can. W. T.

IN REPLY to W. T., there are several good points in favor of a star connection, from the construction standpoint only. Some manufacturers prefer a star connection rather than a delta on account of the smaller number of turns required per coil. A delta connection requires 1.73 more turns than a star connection, but the wire required is of a smaller size. The greater number of turns required by the delta connection makes it necessary to allow more space in the slots for insulation, thus leaving less space for the copper itself. For instance, a coil of 30 turns star-connected would not take up as much space with cotton, silk, or enamel insulation as a coil of 50 turns of a smaller wire would require with the same kind of insulation. The coils of the smaller sized wire are less rigid than coils made of wire of a larger size. The price of magnet wire increases as the size of the wire decreases; also, it is more expensive to wind the coils having the larger number of turns.

As to torque and starting current, take as an example the two motors mentioned by W. T. The delta-connected motor will have a lower starting torque and a lower starting current than the star-connected motor. No doubt the delta connection will also result in a slightly higher power factor, but it is probably safe to say that the two motors will be about equally efficient. The delta-connected motor may run a little more quietly than the one that is star-connected and perhaps it will have less tendency toward vibration of a mechanical nature.

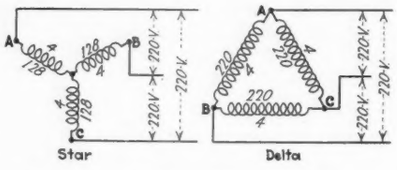
Now, the star-connected motor will have a higher starting current and a correspondingly higher starting torque due to the higher current. The power factor may be a little lower, but the general efficiency remains about the same as the delta-connected motor. Perhaps the mechanical vibration with the star connection may be greater, hence it may make a little more noise.

So far as operation is concerned, there does not appear to be very much difference between a star-connected and a delta-connected motor, when all points are taken into consideration, and each bad point balanced against a good point of the other type of motor. The main things to look for in the characteristics and operation of induction motors are the starting torque, starting current, power factor and efficiency. Ordinarily a little more or a little less noise makes no difference to the buyer or operator. When considering the star-connected motor from the repairman's or winder's point of view, no doubt a preference will be shown for the star connection, especially if there are very many semi-closed slot motors to be rewound as it takes more time to install coils for a delta connection owing to the larger number of turns. As a rule, in reconnecting old windings to new operating voltages, frequencies and phases, it is easier to change a star connection than a delta.

LEE F. DANN.
Chief Electrician,
Dannacona Paper Co., Ltd.,
Donnacona, Que., Can.

TWO motors designed for the same horsepower, one connected star and the other delta, will have practically the same operating characteristics relative to starting current, torque, power factor and efficiency.

By changing a star-connected motor to delta, or a delta-connected motor to a star connection the operation of the motor will be materially affected, if used on the same supply circuit but, if the supply voltage is changed so as to correspond to the new connections, the characteristics of the motor will not be changed.



The general arrangement of coils in star and delta connections is indicated in these diagrams.

A change from a star to a delta connection makes it essential that the size of the wire in the motor coils be large enough to carry the increased line current. This increase in current in a delta-connected motor is 1.73 times the current used when the motor is star-connected, while a change in connections from delta to star reduces the line current used by an amount equal to line current divided by 1.73, and the increase in the operating potential of the motor is 1.73 times the delta-connected operating voltage.

A motor that is star-connected for 173 volts and 100 amp. will operate with the same characteristics when reconnected delta, for operation on 100 volts, and taking 173 amp., but when changed to a delta connection and the motor is operated from the original 173-volt supply circuit, the potential per coil will have been increased 173 per cent. In this case with a potential of 173 volts there would be a tendency to increase the horsepower rating of the motor. This increase in horsepower is not possible with the same amount of iron, the result being that the motor would be more or less overloaded.

Motors as a rule are star-connected, for this arrangement is easier to connect and test, but another very good reason for using the star connection is the possibility of the customer desiring to change the operating voltage. Suppose a motor was purchased with a 220-volt, delta connection. In this case the motor would really be limited to one connection, for a change to a star connection would require a line voltage of 220 × 1.73 or 380 volts which is not a standard voltage. On the other hand, if this motor were originally star-connected for 220 volts, it could be used if reconnected delta, on a line voltage of 220 ÷ 1.73 or 128 volts, which is close enough to 110 volts, a standard voltage, for the motor to operate satisfactorily after the change.

The effect of star and delta connections is very often utilized in starting motors, the winding terminals being brought to a triple-pole, double-throw switch which connects the windings in delta for starting and in star for running.

By referring to the accompanying illustration it will be noted that in the star diagram the group voltage is (line voltage ÷ $\sqrt{3}$) ÷ 4 = 32 volts, while with the delta connection the group voltage is 220 ÷ 4 or 55 volts. The ratio of 55 volts to 32 volts being 1.73, the current in the star-connected coils becomes 1.73 times that in the delta-connected coils when the motors are operated on the same line voltage. The star-connected voltage per leg is line voltage ÷ 1.73 and the current in the star-connected coils is equal to line current. With coils wound for the delta connection, the voltage per leg is line voltage and the current in the coils is line current ÷ 1.73.

Chief Electrician, E. J. MORRISSEY.
Western United Gas & Electric Co.,
Aurora, Ill.

IN ANSWER to W. T., there is practically no difference between the operation of delta- and star-connected motors when the voltage, frequency, horsepower, windage and a few other characteristics are similar. But a motor that is wound for a given voltage and connected star, cannot be reconnected delta and still operate properly on the same voltage, for when a change is made from star to delta, the new voltage is found by dividing the original voltage by 1.73, and the amperage is determined by dividing the former star amperage by 1.73 for the delta amperage.

If there are two motors, as stated, that are of the same make, horsepower, voltage, and number of coils, one connected delta and the other star, there will be 1.73 more turns per coil in the delta-connected motor, but the wire in the coils will have less cross-sectional area in proportion to the ratio of line current ÷ 1.73. Consequently the copper in coils of either motor will weigh the same.

The question of which connection to use is established by the manufacturer, as one connection or the other usually lends itself to a reduction in manufacturing costs. For instance, if a manufacturer wishes to employ women, the wire of which the coils would have to be made for a given size of motor may be too stiff for them to handle, if the motor were connected star, although the women could probably handle the smaller size of wire required by a delta connection.

There are likewise other occasions when a manufacturer is obliged to use commercial sizes of wire in a given frame, for he can by chording obtain the desired voltage exactly with one connection but he may not be able to do so with the other.

Ft. Dodge, Iowa. CLAUDE D. MARTIN.

Electrical Service

AROUND THE WORKS

For this section short articles describing ideas and practical methods devised to meet particular operating conditions are invited from readers. The items may refer to inspection, overhauling, testing, and emergency or special installations.

Chart for Finding Physical Properties of Copper Wire

THE accompanying copper wire chart illustrates the wire tables graphically and the regularity of the sizes of wire shows that the tables were designed with a uniform variation when referred to a logarithmic scale. It will be noted that the sizes of wire given in the gage numbers are spaced evenly. The difference between the diameters of No. 29 and No. 30 wire is 1.3 mils, while the difference between the diameters of No. 3/0 and No. 4/0 wire is 50 mils. The reason for the difference in the increment or decrement is that, for all practical purposes, wire with a diameter of 459 mils would serve as well as a wire with a diameter of 460 mils.

It was then decided to make the wire tables with a constant ratio between the areas. This was not a needless complication, but rather a simplification. The user of the American Wire Gage is fortunate because it is the only system that has any scheme of regularity and adheres strictly to that scheme. The three straight lines on each side of the accompanying chart demonstrate conclusively that in the American Wire Gage there is a constant ratio between the area, resistance and weight of one gage number compared with that of another.

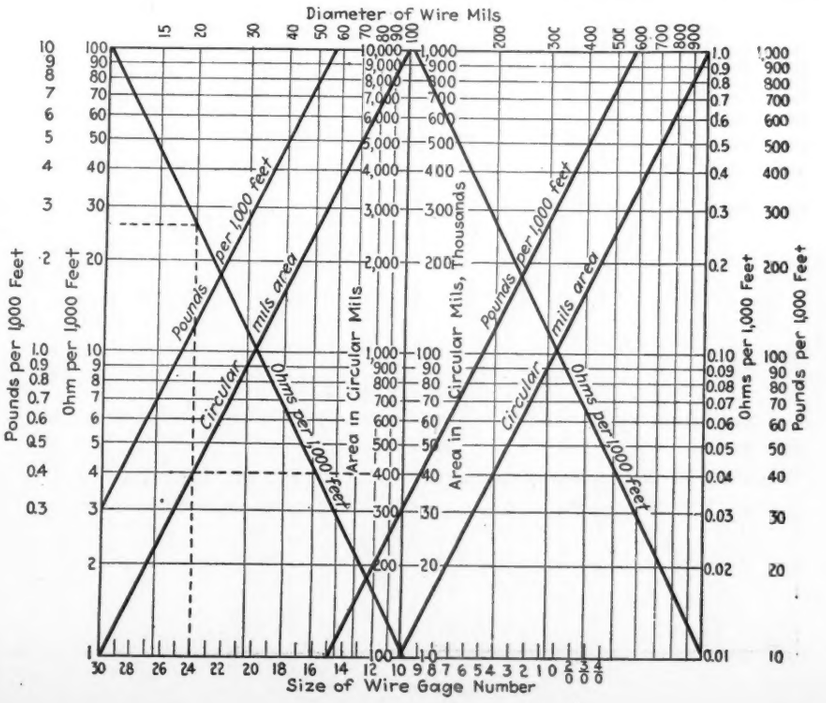
To use the chart, trace vertically upward above the desired size of wire to the intersection of that line and the diagonal line marked *Circular Mils Area* and from this intersection trace horizontally to the column with the same marking where the area in circular mils is indicated. To find the pounds per 1,000 ft. continue the vertical tracing until the diagonal line marked *Pounds per 1,000 ft.* is met and read the value given by the horizontal projection in the column marked *Pounds per 1,000 ft.* The ohms per 1,000 ft. is found in the same manner.

An example will illustrate the above procedure and also demonstrate what degree of accuracy may be expected. Suppose for instance it is desired to find the area, weight and resistance of No. 24 wire. To find the area of the wire, start from the point at the bottom of the chart marked No. 24 gage and trace the dotted line which extends upward in a direction vertical with the bottom of the chart to the diagonal line marked *Circular Mils Area.* From the intersection of these two lines trace horizontally to the column marked *Circular Mils Area* to find area of No. 24 gage wire. By continuing to trace the dotted line upward until it intersects with the diagonal line marked *Pounds per 1,000 ft.*, and further on to the diagonal line marked *Ohms per 1,000 ft.*, the weight and resistance of the wire may be found.

On the parts of the chart marked with the larger graduations, it is evident that the values may be read to the second significant figure, the third being estimated. With the finer graduations, it is necessary to estimate the second significant figure. After a small amount of practice, the chart may be used with confidence and with the knowledge that the figures obtained are only slightly in error. C. F. CAMERON.
Rock Springs, Wyo.

The cross-sectional area, weight and resistance of No. 30 to No. 4/0 copper wire can readily be determined from this chart.

In order to determine the area, weight or resistance of a certain size of copper wire, trace upward from the gage number of a certain size of wire to diagonal line marked *pounds per 1,000 ft., circular mils area, or ohms per 1,000 ft.*, as the case may be, and from the intersection between the line drawn vertically and one of the diagonal lines trace horizontally to the column marked the same as the diagonal that has been intersected by the vertical line.



Use of Potentiometer to Supply Power for Signal Systems

FOR economical reasons, lighting circuits are now frequently used to supply electric current to low-voltage systems in place of the much used wet or dry cell batteries. The increasing use of low-voltage equipment, such as indicators, bell systems, telephones and the like has induced a large organization to utilize potentiometers with 110-volt, d.c. circuits, whenever practical, to supply the desired low voltage.

The simple potentiometer used consists of a correctly designed resistance coil placed across the mains with taps to give the desired voltage. The load characteristic of a potentiometer is similar to the external characteristic of a self-excited, shunt-wound generator; that is, an overload causes a rapid drop in voltage, which may fall to zero. For any particular load, the voltage may be increased by decreasing the total resistance of the potentiometer, or by taking off the load from a higher tap. If a higher tap is used, however, the voltage delivered at no-load is increased. Hence, for economical operation, the balance between the total current consumed and the no-load voltage is the problem of design.

This latter statement may be better understood by referring to Table A. This table gives the calculated performance of a potentiometer having a total

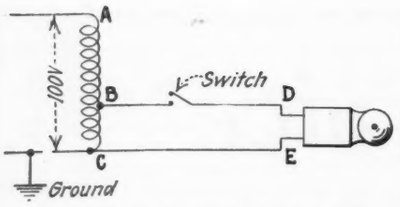


Fig. 1—Typical potentiometer layout for low-voltage signal systems with only a small variation in the current demands.

The direct-current lighting circuit leads are connected to the potentiometer at *A* and *C*, the ground connection being connected to lead *C*. The location of top *B* together with the resistance of coil *AC* is selected in accordance with the lighting voltage and the current requirements of load *DE*.

resistance of 100 ohms and a 20 per cent tap to supply the low-voltage circuit. The potentiometer is connected across a 100-volt supply. The table gives the performance of the potentiometer under different loads.

Referring to Fig. 1, the effective resistance of *BC* and load in parallel $= [20\,DE \div (DE + 20)]$. In this case the resistance *BC* is represented by 20 ohms. The total resistance in ohms across the service line *AC* is [80 + (effective resistance of *BC* and *DE* in parallel)]. In this case 80 ohms represents the resistance between *A* and *B*. The total current in amperes supplied by the service line is 100 ÷ [80 + (effective resistance of *BC* and *DE* in parallel)]. Voltage between *DE* or *BC* = (current through *AB*) × (effective resistance of *DE* and *BC* in parallel). The current through the load = (voltage of *DE*) ÷ (resistance of load).

Table B shows the increase in voltage and current obtained through the same load values when a 20 per cent tap is taken from a 10-ohm coil instead of a 100-ohm coil, as was the case in section A of the table. The maximum output in watts is obtained from the potentiometer when the internal resistance *BC* and the load resistance *DE* are equal. This fact may be often used to advantage as the basis of design.

For example, if current is to be supplied to a two-circuit, electro-mechanical gong fire signal system, supervised by the full operating current of 125 mil.-amp. per circuit, a constant load of 0.25 amp. at 20 volts is required. By Ohm's law the resistance of the external circuit is $R = E \div I$, or $R = 20 \div 0.25 = 80$ ohms. Making use of the maximum output, as explained in the preceding paragraph, fixes the resistance of the *DE-BC* section.

The first column of the table gives the resistance of the load. In Fig. 1 let *DE* represent a load of which the resistance can be varied at will, and *AC* a potentiometer having 100 ohms total resistance with a 20 per cent tap at point *B*. Now, when the resistance of *DE* is 40 ohms, we find that the effective resistance of *BC* and *DE* in parallel, that is, the effective resistance of 20 ohms in parallel with 40 ohms, is equal to $(R_{BC} \times R_{DE}) \div (R_{BC} + R_{DE}) = (20 \times 40) \div (20 + 40) = 800 \div 60 = 13.3$ ohms, as given in the second column, first line. Then the total resistance between points *A* and *C* equals 13.3 + 80 = 93.3 ohms, as given in the third column. The total current supplied to the potentiometer will be 100 ÷ 93.3 = 1.07 amp., as given in the fourth column. To find the voltage supplied to the load, we first determine the voltage drop over *AB*, which is equal to 1.07 × 80 = 85.6 volts. Subtracting this from the line voltage we get 100 — 85.6 = 14.4 volts supplied to load *DE*, as given in the fifth column, first line of table. Then the current input to the load will be the voltage delivered by the potentiometer divided by the load resistance which equals 14.4 ÷ 40 = 0.36 amp. as given in the sixth column, first line. Comparing the first and fifth columns, we find that a change in the resistance of the load will cause a large change in voltage delivered to the load.

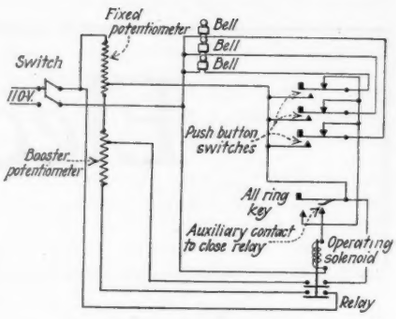


Fig. 2—Using a booster potentiometer to supply intermittent demands for more current.

The fixed or permanently connected potentiometer handles only light loads, such as ringing small bells and the like. When heavier demands for current must be met, the booster potentiometer is cut into the circuit by means of a relay.

As the voltage across *DE* is 20 volts, section *AB* must then absorb the difference between the load and supply voltages, in this case 100 — 20, or 80 volts. But since the resistances of the *BC* and *DE* sections are equal, the current in each leg is 0.25 amp. and the current through the *AB* section is 0.5 amp. which fixes the resistance of *AB* as $R = E \div I$, or $80 \div 0.5 = 160$ ohms, which takes care of the 80 volts between *A* and *B*. It is also desirable to check the no-load voltage obtained when the external load is removed. In this case the resistances of the *AB* and *BC* sections are 160 and 80, respectively, making a combined resistance of 240 ohms between the 100-volt service lines. Since the *BC* section is a third of the full resistance between the service lines, the no-load voltage is 33.3 volts.

The great advantage of potentiometers is most apparent when the external load is intermittent in character, in which case a booster potentiometer may be brought into service by means of a relay and in this way take care of any heavy load during the time for which the load is to be supplied. Booster relays might be used for fire signal systems where the full operating current is not required for supervision, for all-ring, classroom-bell operation in school buildings and for many other uses. Fig. 2 indicates a typical layout for such a system.

Commercial resistances are rated in watts, in which case the current supplied is dissipated as heat or I^2R losses. Generally, commercial resistances are rated 200 watts continuous duty and 500 watts for 20 seconds. The simplest form of resistance for potentiometer use is a bare wire wound on an insulating tube. Adjustment of voltage can be conveniently made by means of a movable slider. In another form of potentiometer permanent taps are brought out from the coil, and the joints, together with all of the coil, are then covered with a vitreous enamel and fired.

Potentiometers may be mounted in the open on a slate switchboard or enclosed in a metal cabinet. If enclosed, asbestos wiring had best be used because a non-ventilated cabinet will often radiate more heat than a ven-

Voltage and Current Characteristics of Potentiometer Under Different Load Conditions

Resistance of Load *DE* in Ohms	Effective Resistance of *VC* and *DE* in Parallel	Total Effective Resistance Between *A* and *C*	Ampere Input to Potentiometer	Volts Applied to Load *DE*	Load, *DE*, in Amperes	Load, *DE*, Watts
A—Total resistance of potentiometer coil AC equals 100 ohms						
40	13.30	93.3	1.07	14.4	0.362	5.17
20	10.00	90.0	1.11	11.1	0.550	6.11
10	6.70	86.7	1.15	7.7	0.780	6.01
5	4.00	84.0	1.19	4.8	0.960	4.61
3	2.60	82.6	1.21	3.2	1.050	3.36
1	0.95	80.9	1.24	1.1	1.200	1.32
B—Total resistance of potentiometer coil AC equals 10 ohms						
40.0	1.90	9.9	10.1	19.2	0.48	9.21
20.0	1.80	9.8	10.2	18.4	0.92	16.9
10.0	1.70	9.7	10.3	17.3	1.73	29.9
5.0	1.40	9.4	10.6	15.0	3.00	45.0
3.0	1.20	9.2	10.9	13.1	4.40	57.6
1.0	0.63	8.6	11.6	7.3	7.30	53.3
0.5	0.40	8.4	11.9	4.8	9.60	46.1

tilated one for the reason that the whole cabinet is raised an equal amount above the ambient temperature and the whole surface is available for heat dissipation and thus localized hot spots are more often avoided. However, each case must be treated individually, and as most potentiometers for this class of work need not radiate more than 50 watts continuously, the usual precautions accorded to electric lamps of similar watt consumption are all that is necessary.

LEO S. LOOMIE.
New York, N. Y.

Savings Made in Repairing Water Wheel Casing by Arc Welding

AN ELECTRIC arc welding operation that was recently performed on a water wheel saved the company involved approximately $800 and the job was completed in 11 weeks less time than would have been the case if it had been necessary to wait for a new section of the casing.

This water wheel casing was badly in need of repair, for the bearing had become worn, thus allowing the wheel to move over and wear away a section of the casing. The worn section was about 10 in. wide by ¾ in. to 1 in. deep around the entire periphery of the casing. In some spots the casing was worn away entirely and in others the parent metal was only 3/32 in. thick. Some holes up to 1 ft. long had previously been covered by a patch on the outside.

A Westinghouse 200-amp., three-phase, 25-cycle, 550-volt, portable arc welding set was used on this job. The very thin section and the part that was entirely worn away were first spanned by circular hoops made of steel rods. The first rod, § in. in diameter, was welded to the neck of the casing, another §-in. rod was welded to this one and a §-in. rod was welded to the second rod, a space being left between this third rod and the next one, large enough to insert a §-in. rod. After a ½-in. rod was welded to the cast-iron casing, the §-in. rod was inserted in the place left vacant for it, and welded to the rod on each side of it, thus bridging over the weakest part of the casing. The rest of the worn section was then filled in and the surface of the casing ground to a smooth finish by means of a portable grinder.

The striking feature of this job is that it was completed at a cost of approximately $200 and in seven days time, whereas a new casing would have cost $1,000, and could not have been obtained for at least three months.

This worn-out waterwheel casing was repaired by arc welding.

The thinnest places were reinforced by steel rods and then built up to the required level, after which the surface was ground smooth.

Using Test Receptacles in Checking Motor Loads

UNTIL a few years ago motor testing was a problem and tests were made only in a very superficial manner, due primarly to improper testing facilities. Today, as a rule, plants of any appreciable size are fairly well equipped with testing instruments, but frequently no provision is made at the motor or starter to enable the tester to connect his instruments without danger, inconvenience, and a certain loss of motor service.

In our plant 98 per cent of the motors operate at 550 volts, a.c. This is a dangerous voltage, especially around paper mills, where so much moisture is present. Frequent tests are necessary, due to reconstruction or rearrangement of drives and motor changes, for our plan is to keep the motors loaded as close to their ratings as possible. A method of connecting instruments and the necessary transformers was therefore required in order that tests may be made at any time without shutting down the motor even for a very few minutes. With this in view each starter is now equipped with a Square D safety switch. These switches are fitted with test receptacles which are connected in series with the incoming and outgoing leads of the switch. These test receptacles are now utilized in making all tests by plugging in the necessary plug connectors.

Our instruments consist of a triple-range voltmeter with scales 0 to 150, 0 to 300, and 0 to 600; two 5-amp. ammeters; a polyphase wattmeter, and two variable-ratio current transformers. The current transformers have three ratio taps brought out of the windings to terminals mounted on the case and are also of the hollow, or open type. The three taps brought out to terminals have 10-amp., 20-amp., and 40-amp. capacity, which are used on loads of 40 amp. or less. For loads greater than 40 amp. a different number of turns is carried through the transformers, depending on the capacity required. The largest ratio is 800 to 5, with only one wire through the transformer.

Extra-flexible cable is provided for use with the plugs connecting to the test receptacles. These plugs fit tightly into the receptacles in the line switches. In case an ammeter test is sufficient, two pieces of cables with plugs are plugged into the proper receptacles so as to short-circuit two of the three switch-blades. The current transformer is then connected around the third switch blade by other cables and plugs. With the ammeter connected to the secondary of the transformer, all that is necessary in order to take a reading is to open the knife switch. These switches, of course, are operated from a handle outside the box and all three blades break at the same time.

When a wattmeter test is required a few more connections have to be made. Two current transformers are connected one to each outside leg of the switch and the center blade is again short-circuited with a piece of cable. The potential coils of the wattmeter are wound for 600 volts; so it is unnecessary to use potential transformers when testing on a 550-volt circuit. Spring clips made from patent or spring clothes pins are used to connect the potential leads of the meter to the line. The potential leads are not placed until the line switch is open; then they are clipped onto the ends of the projecting switch blades.

The test receptacles and plugs required for testing were obtained from the Square D Co. Two sizes of flexible cable are used, No. 6 for testing motors up to 75-hp. rating and No. 2/0 for testing the larger sizes. Cables are made up in convenient lengths to suit the various installations. One man does all the testing, as no one else is allowed to take meters out of the shop.

The cost of the equipment exclusive of the meters and transformers was $500, which includes all test receptacles, plugs, cable, and installation labor. This cost has been many times returned to the company since the installation.

Recently a test disclosed the fact that a 50-hp. motor was doing about 21 hp. of actual work. At the time a 50-hp. motor was needed to drive a large pump; so the underloaded motor was used for this purpose and was replaced with one of 20-hp. capacity, saving the cost of a new 50-hp. motor. Of course, these extreme cases are rare, but it often happens that we are able to replace a 40-hp. motor with one of 30-hp. or a 25-hp. motor with one of 20-hp. rating. The tests also prove very valuable in case of a motor burning out as we are able to tell from our records what size motor will do the work. It often happens that a smaller motor is available for the job, but it rarely happens that a larger one is available. If we had no records we would not dare to install a smaller motor. In the past two years numerous tests have been made about the mill, but no accidents have occurred and no equipment has been shut down to permit testing.

Chief Electrician, LEE F. DANN.
Donnacona Paper Mills, Ltd.
Donnacona, Quebec, Can.

MECHANICAL MAINTENANCE OF *Power Drives*

This department will furnish mechanical details of installation, operation and maintenance of equipment in the path of power service from the first mechanical driving element through the auxiliary transmitting equipment to all driven machines.

Changing the Method of Driving Exhaust Fan Solved Motor Trouble

FREQUENTLY a baffling problem will cause the engineer of a modern industrial plant annoyance of the most exasperating nature; the more illusive the cause, the more trying it is on the nerves and patience of the engineer, as exemplified by the following experience. The Inspector for the State Department of Labor ordered that an exhaust fan be installed in the lacquer spraying room of an industrial establishment. Although the lacquering was carried on under a hood equipped with an exhaust fan, a considerable amount of fusel oil fumes escaped into the room. The Inspector held this to be detrimental to the health of the girls employed in the room, and so ordered additional ventilating facilities. Accordingly, a 36-in. exhaust fan, which was driven by a direct-connected, ¾-hp., 250-volt, series-wound, d.c. motor was installed in the upper half of one of the windows.

The installation functioned fairly satisfactorily for a while, until one day without apparent cause the armature burned out. The Inspector happened to call at the plant while the fan was inoperative and ordered that the fan be kept running all of the time, without any excuses. Consequently a spare armature was purchased and installed, but in a very short time the second armature burned out.

A considerable amount of new construction work was going on in the plant, and the Plant Engineer had left the maintenance entirely to the foreman of the maintenance gang with instructions to bring only matters of real importance to his personal attention. Consequently the maintenance foreman secured three spare armatures and replaced and rewound them as fast as they burned out, although he had difficulty in keeping up the pace. Finally, all four armatures were in the repair shop at one time.

The Superintendent of the Lacquering Department was annoyed because the fan was frequently inoperative, also the Inspector threatened criminal prosecution, and called the attention of the Plant Engineer to the difficulty. An immediate investigation was undertaken. Load tests, which were taken, seemed to indicate that the capacity of the motor was ample. A recording ammeter kept in the circuit for several weeks indicated that the load did not fluctuate appreciably and the difficulty appeared shrouded in mystery.

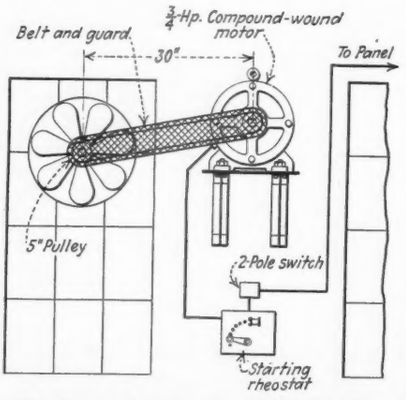
The engineer decided to watch the installation closely and visited the room several times a day for several weeks without results. At last his patience was rewarded. One day he observed the fan slowing down without any apparent reason, finally coming to a standstill, then actually reversing itself and driving the motor as a generator.

The fan was installed in a window on the sixth floor facing west and overlooking a bay. A high velocity west wind striking the fan blades would convert it into a wind turbine and drive the motor in the reverse direction as a generator across the 250-volt line, thus burning out the armature.

The installation was then modified as follows: The motor was disconnected from the fan and a 5-in. pulley installed in its place. A ¾-hp., compound-wound motor, with about 25 per cent compound field, was mounted on a wall bracket about 30 in. from the fan and belted to the fan pulley. The modification proved very satisfactory. When a strong gust of wind would strike the blades and attempt to reverse their direction of rotation the fan belt would begin to slip and in the case of a very strong wind would be thrown off. In this way the belt served as a safety link which protected the motor against the heavy overload of the sudden gust and the consequent reversal which burned out the motor. As the belt was not thrown off frequently, it was not very annoying, and the belt was replaced easily. Although individual, direct-connected motor drives have advantages in many installations, there are many cases where a safety link is necessary between the motor and its load, as in this instance.

The installation of an exhaust blower leading to the roof and terminating in a revolving or other type of roof ventilator perhaps would have been a more satisfactory solution, but in this case it was objected to for several reasons.

Electrical Engineer,
Ampere, N. J. E. OGUR.



The belt is thrown off automatically and saves the motor when a high wind reverses the direction of the fan.

Formerly a direct-connected, series-wound, d.c. motor was mounted in the window, but strong gusts of wind reversed the direction of rotation and burned out the motor. By using a compound-wound, d.c. motor mounted on the platform and connected by a belt the motor is saved because the belt serves as a safety link and is thrown off by an overload.

Changing Method of Feed Solved Lubrication Problem

MANY times the modernization of the lubrication of old equipment is difficult because the construction of the bearings, unless altered in some way, does not permit using a different lubricant than the machine was originally designed to use. This is particularly true, in many instances, where it is desired to change from a grease to an oil lubricant. Often the old bearing is not tight enough to retain the oil. This is sometimes overcome by using a bottle, wick, or drop oiler which feeds a definite amount of oil to the bearing continuously. In addition, care must be exercised to see that the oil grooves are cut properly to distribute the lubricant.

An interesting problem, however, arose recently in connection with the modification of the lubrication system for a crusher which was originally built for grease lubrication. The grease, which was placed in a deep chamber reservoir, was supposed to flow down to the bearings as needed. It was found, however, that the heavy grease used, caked and failed to flow. Oil ran through too quickly, as this was a loose-fitting bearing. Also, a lighter grease ran through too rapidly.

The difficulty was overcome by installing a plug with a much smaller opening at the bottom of the grease chamber and using a grease with a light body. This small opening restricted the flow of the light grease to the amount required for the bearing. The grease was too light in consistency to cake. Plugs with openings of different diameters were tried until one was found which reduced the flow of the light grease to the proper amount required for the bearing.

Chicago, Ill. F. E. G.

Simple Methods of Quieting Noisy Gears

THERE are many reasons why gear drives are noisy. They may be made with cast teeth, they may be running at a speed too high for their particular type, they may be meshed too tightly, they may be badly worn or running on shafts that are not parallel. There is a certain amount of noise—small, to be sure—every time a tooth strikes its mate, and this, multiplied by the number of teeth and speed of revolution, builds up the roar that is so nerve racking and so unnecessary.

Recently the noise from a machine in a plant attracted notice. It was impossible for a person standing alongside the machine to be heard, except when shouting. The drive was by a 4-in. belt running at 1,800 f.p.m. from the first shaft through three pairs of gears to the fourth shaft, which turned at 3 r.p.m., a reduction of 160 to 1. Somewhere in those gear trains was the noisy member. The workmen had become used to it, looking on it as a necessary evil, and said the machine had always been noisy.

It sounded like gears too closely meshed and, from the frequency of the pulsations, it was on the first shaft. A request for a flashlight and a chance to investigate showed that the gears were bottoming in the first two trains. They were all under the machine and during the various periods of repair the bearings, which were bolted to the planed underface of the frame, had been "socked up tight" with a big wrench and there they stayed.

With such constructions, it is customary to give the bolt holes $\frac{1}{16}$ in. of play and finally to secure the bearings by the big wrench method after a careful alignment, or else to use dowels. Undoubtedly the builder had had the shafts properly lined up, but evidently the repair crew had trusted to the bolt holes to space the shafts as they ought to be. Being under the machine where he had to lie on his back to work, the repair man had taken the quickest and easiest way, even if the machine and the employees did have to suffer.

Loosening up the first shaft's bearings and blocking it all the way back while the bolts were tightened, a start was made toward correction. Then the second shaft was loosened and moved back half the amount of the first one. The space between the gears could be seen then when the pulley was rotated back and forth. The final procedure was to cut sections of hard maple, which were wedged in between the pairs of bearings at right angles to the grain. This made it sure that they would not come together again, and if they fell out, it would show that some movement had taken place.

Any time that gears under inspection show evidence of rubbing action at the root of the teeth, noise and improper setting may be looked for. In this case it was evident at a glance. When the machine was started up again, it ran almost noiselessly.

Gear teeth are so cut that their action is rolling in mesh, not rubbing, and there is everything to lose by not maintaining the correct mesh. Teeth should never bottom. There is purposely cut at the bottom a clearance which is approximately one-tenth of the height of the tooth. When the meshing of a pair of gears maintains this clearance, almost no noise will result from running and the wear of teeth will be reduced to a minimum.

Side clearance is also provided for when the teeth are cut. This amounts to 0.002 or 0.003 in. No easier way of setting gears can be followed than to place a slip of newspaper alongside two of the teeth at the point of tangency. This clearance is readily discernible to the eye if one of the gears is moved back and forth.

One of the most frequent violations of this gear bottoming rule is found in machine shops in connection with lathe change gears. When these gears are changed, there is always a swing gear or one studded in a slot, which is set to make up for differences in diameters, or to connect up the train. Machinists are prone to push these gears up hard as they are tightened; the result is that bearings and teeth get unnecessary wear and there is a grinding noise set up that should cry aloud to supposedly trained men. Moved apart $\frac{1}{32}$ in., the gears would run quietly and wear would be minimized.

The use of grease and oil may be commended in some cases, but when lubricant is used to cover up or relieve too tight a setting of cut gears, it is wrong practice. A film of lubricant may be needed in most cases, but that film is immediately broken down where no clearances exist.

DONALD A. HAMPSON.
Plant Superintendent,
Morgans & Wilcox Mfg. Co.,
Middletown, N. Y.

Operating Comparison of Variable-Speed Transmission and Variable-Speed Motor

VARIABLE-SPEED drive and control for assembly conveyors and other equipment which it is desirable to operate over a range of speeds, are ordinarily obtained either by using a variable-speed transmission or a variable-speed motor. Conveyors usually travel at a very low speed and any additional high reduction between the motor and the conveyor is obtained by means of suitable gear reduction units which give a fixed reduction ratio. The experience of the Hupp Motor Car Corporation, Detroit, Mich., and the comparative cost figures should be of interest to other concerns with similar power-transmission and variable-speed problems.

This company has six style O-E Reeves variable-speed transmissions (Reeves Pulley Co., Columbus, Ind.) in operation at the present time. Assembly conveyors which are operated from the Reeves transmissions range from 200 to 300 ft. in length. The chassis-assembly conveyors, three in number, are typical of all these drives. Each is 244 ft. long and is driven at speeds of 3 to 12 f.p.m. in conveying the chassis through the various assembly operations. In the operation of these conveyor lines smooth control and increment of speed with close regulation are required over a wide range.

Power is supplied to each of the chassis-assembly conveyors from a constant-speed, 3-hp., 1,200-r.p.m. induction motor which is connected to a variable-speed transmission and a gear-reduction unit. The latter has a fixed ratio of 95:1 and the variable-speed unit gives a smooth variation in a 4:1 ratio. Conveyor chain speeds from 3 to 12 f.p.m. are readily available.

The use of a variable-speed induction motor would, in this plant, be the only practical alternative for obtaining suitable variation in conveyor speed.

Three such motors are used at the Hupmobile plant for driving three final-assembly conveyors. They have proved much less satisfactory in fineness of regulation and in dependability of operation. These motors are equipped with elaborate control equipment, but are capable of only a 2:1 speed variation which is obtained in only nine steps from the highest to the lowest. Small increments in speed are not possible.

Tabulations that have been made render it easily possible to compare the annual fixed costs for the variable-speed transmission unit with those for a variable-speed motor which, with suitable reduction gears, would give a somewhat similar result.

The use of such a variable-speed motor and gear unit would involve annual fixed charges of $71.42, considering only depreciation and average interest at 6 per cent figured over a 10-yr. period. The Reeves drive actually in use, when analyzed in the same way, shows annual fixed charges of $61.84.

The annual saving is, of course, not large but the operating advantages of the transmission unit are of additional importance. The variable-speed transmissions are, in addition, more dependable in operation and there has been no expenditure for maintenance on them in four years of use.

Furthermore, aside from its less flexible speed control characteristics the variable-speed motor must be a much larger unit than the constant-speed motor used with the variable-speed transmission. To deliver 2 hp. at half speed requires a motor capable of developing about 5 hp. at full speed. This results in much lower efficiency at all speeds and loads. At full speed and developing 3 hp. the efficiency would be 81.5 per cent and at half speed, where the load is 2 hp., the efficiency would be only 41 per cent. A 3-hp. constant speed motor would have an efficiency of about 85 per cent, varying little with the variation of load between 66 and 100 per cent of motor capacity. The use of the constant-speed motor results in a saving of 1.87 kw. at low speed.

On the other hand, the variable-speed drives can be locked at any speed, thus assuring a set production rate. This is invaluable in maintaining a predetermined production schedule. Close maintenance of a fixed speed has not been possible with the variable-speed motors, as now installed, and their control over conveyor movement has, on the whole, been far less satisfactory than that obtained with the use of the variable-speed transmissions.

PAUL J. ZIEGELBAUR.
Assistant Superintendent of Maintenance,
Hupp Motor Car Corp.,
Detroit, Mich.

In the Repair Shop

This section is devoted to repair work on electrical and mechanical equipment. Special attention is given to shop or bench tools and short cuts or improved methods of handling work of this character. Contributions are always welcome.

Simple and Inexpensive Type of Cross-Over Connector

IT SEEMS rather surprising that among the numerous patented wire connectors, there are none that are designed for use on cross-over connections. In my own work I have discovered the need of a cross-over connection from time to time and, disliking to make a basket splice which at the best would be bulky and unsightly, I found that two types of connectors could be made quite easily in the shop.

For small wires, the connectors may be made from heavy sheet copper of a gage to correspond to the required carrying capacity of the joint. In making the connector a flat sheet should first be cut out, as shown at *A* in the accompanying illustration, and then bent into form, as shown at *B*. The connector is now ready to be pinched onto the wires and soldered into place. Even when taped, these connectors make only a small bulge on the wires.

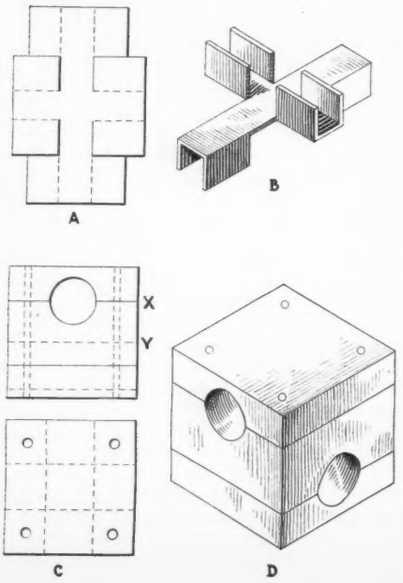
For large wires, a stronger type of connector is needed. A piece of brass of cubical shape should be used for these. Through the cube drill two holes exactly the size of the wires to be connected, the relative positions of these holes being shown at *C* in the illustration. Next drill four small holes down through the corners of the cube, and with a hacksaw cut through on the lines marked *X* and *Y*. The finished connector is shown at *D* in the illustration.

To assemble, place the three pieces in position on the wires, insert four through bolts in the small holes, and take up on the nuts until the cut faces pull together. The hacksaw in cutting removes enough stock so that the parts of the connector clamp down firmly on the conductors.

JAMES P. MARSHALL.
Providence, R. I.

These handy cross-over connectors make only a small bulge on the wire, even when taped.

The type of connector shown at *A* and *B* is used on small wires, while the one shown at *C* and *D* is suitable for large wires.



Quick Method of Replacing Worn Collector Rings

A FEW years ago I took charge of a plant containing several rotary converters which were originally designed for operation at 25 cycles, but had later been rebuilt for 60-cycle operation.

The original a.c. brushes and slip rings were still in use, but the new rotor speed of 1,200 r.p.m. as compared with the original speed of 500 r.p.m. had proved destructive to the copper leaf brushes and the slip rings.

After some experimenting, a carbon type brush was found that would operate satisfactorily under the exacting conditions of high speed and heavy current, but by the time we had found a satisfactory carbon brush the collector rings were so worn and pitted that it was decided to replace them. As they were found to be forced or shrunk on a heavy iron spider which was heavily insulated with mica, it was decided to do as much of the repair work as possible directly on the job in order to avoid delay in the repairing of the rings. The following method was employed:

A portable commutator turning tool was mounted on the bearing cap at the a.c. end of the machine, and as the frame of the rotary was insulated from the ground, we could clamp the cutting tool directly on the bearing cap with no fear of burning the cutting point. To obtain the desired low speed for the rotary converter, a water barrel resistance was cut in the positive armature lead circuit, so that full voltage, 650 volts, could be applied to the field from the station bus. This arrangement gave ample power at any desired low speed.

While the rotor was running at reduced speed, the old rings were all trued up to the same diameter. New rings, cast from a special alloy, were then ordered from a local foundry and machine shop. These rings were bored so that their inside diameter was $\frac{3}{32}$ in. less than the outside diameter of the old rings, as the new rings were to be shrunk in place.

These new rings, which measured about $13\frac{3}{4}$ in. outside diameter, 11 in. inside diameter, and $1\frac{1}{2}$ in. wide, were expanded about $\frac{1}{8}$ in. by the heat of six gasoline torches. After the new rings had cooled and shrunk into place, the cutting tool was again used to true them up. The job was completed in about 12 hr.

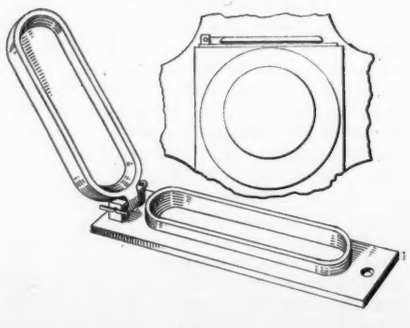
PHILIP N. EMIGH.
Chief Engineer,
The Mountain Water Supply Co.,
Indian Creek, Pa.

Handy Oil Well Cover Permits Easy Access to Bearing

IN THE plant where the writer formerly had a large number of motors in his care, it was necessary to have ready access to the oil rings when the motors were started up after a regular 24-hr. shutdown during cold weather, for the oil at such times generally congealed to the consistency of vaseline. Under these conditions, the oil rings will not turn when the motors are started, and the bearings will often heat up locally before the oil is thin enough to allow the rings to revolve.

Most motor manufacturers equip their motors with stamped steel covers, which are fastened with screws over the top of the oil well. On the other hand, most of the men who started the motors in our plant were rated only a little higher in rank than common laborers; so the oil rings used to be neglected, for these men seldom had a screwdriver to remove the oil well cover so that they could start the oil rings turning. We decided to devise an oil well cover that would keep the dust out of the bearing and yet allow ready access to the bearing, for inspection purposes. The result of our efforts to devise a cover is shown in the accompanying illustration. We had no facilities for making these covers of cast iron, but there were a number of large, junked motor bearings on hand, so we

This oil well cover enables the operator to gain quick access to the oil ring of a motor bearing.



made the covers of white metal. These bearings were melted in an ordinary stove and cast in sand molds at the electrical shop.

A number of our Crocker Wheeler motors had broken oil well covers; so we used these as patterns. None of our electricians was experienced in foundry work, but as they had a general idea of how castings are made, they soon turned out beautiful castings that required very little finishing. The white metal proved to be nearly as hard as cast iron and, after the covers were installed, no bearing troubles were experienced on the motors so equipped.

Possibly some of the readers of INDUSTRIAL ENGINEER may believe that it is cheaper and more satisfactory to purchase oil well covers from the manufacturer, but the writer is of the opinion that it would be rather difficult to secure covers of this kind for all types of motors. This is especially true if one has some 30 or 40 different sizes of motors produced by a dozen different companies. I have recently been informed that one of the motor manufacturers is now equipping his motors with a cover very similar to the one just described, with the exception that the covers are made of stamped steel and a spring is used to keep the covers closed when the bearing is not being inspected.

CHAS. A. PETERSON.

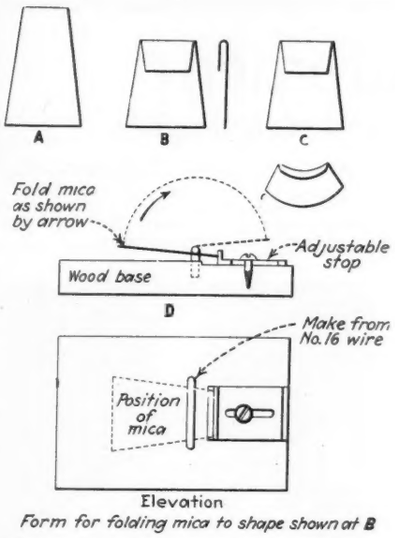
Fairbanks, Alaska.

Simple Method of Reinforcing Mica V-Ring

MANY times it is desirable to reinforce a mica V-ring in a commutator, either on account of its having been patched or when using home-made rings. Nearly all factory V-rings are made in one piece, whereas home-made rings are made in two pieces, which leaves a crack or opening at the point of the V. This is an undesirable condition, as current may leak through this opening and cause the commutator to fail in service.

An easy and practical method of reinforcing mica V-rings, which will be described later, has been used successfully for many years. All of the material needed for one V-ring is a few ounces of No. 4 grade white India mica. This is a standard grading and can be obtained from your regular source of supply of insulation, No. 4 grade white India mica being about the right size for most jobs. India mica is recommended because it splits easier and more evenly into thin sheets than do the various American grades of mica.

The mica is first cut into wedge-shaped pieces as shown in the accompanying illustration at *A*, the point of the wedge being left blunt. The exact size of the mica should be determined from the mica V-ring. The wedge-shaped pieces are then split into thin sheets 0.002 in. to 0.003 in. thick. After splitting, the thin sheets are folded, as in *B*, by means of the adjustable device shown at *D*. Several thin sheets may be folded at a time, taking care to make the legs of the V the same length as the height of the mica V-ring and the width of the bevel part of the ring. The legs will be of unequal length in most cases. While folded, the sheets are rolled or bent in a direction at right angles to the first fold. This rolling gives each sheet a circular shape to fit the inside of the V-groove in the commutator. The rolling is done with the thumb and forefinger of each hand, the work being done on a hard surface.



Form for folding mica to shape shown at B

This shows how the reinforcing pieces of mica are cut and formed.

These pieces of mica are used to line the commutator V in such a way that each piece will overlap the one previously put into place in the same way that shingles are laid. Two layers of mica should be put in the commutator and then the mica V-ring is put into place inside of the two layers of mica, after which the commutator is tightened in the usual way.

If after thoroughly cleaning out the commutator V, the surfaces are coated with shellac and the mica is put in place while the shellac is wet, the mica insulation will then be held more securely. The old mica V-ring should be cleaned of all dust and dirt and given a coat of shellac before using, which should be allowed to dry before the V-ring is put in place. C. B. KECK.

Cleveland Heights, Ohio.

How to Make Rheostat for Testing Fields of D.C. Motors and Generators

TESTING the fields of direct-current motors and generators frequently requires a rheostat of such capacity in the first few steps that only a comparatively expensive commercial rheostat will suffice. To meet this need for a suitable and inexpensive rheostat in an Eastern manufacturing plant, one was built, mostly with material on hand, as described below.

The 230-volt motor for which this rheostat was first designed has a shunt resistance equal to 36 ohms, and is of the adjustable-speed type, 300 to 900 r.p.m., rated at 48 hp. for 1 hr. with a rise of 50 deg.

The rheostat has a range from 0 to 100 ohms and from 100 to 200 ohms, adjustable in 10-ohm steps, with a current capacity of 5 amp. on the first step and 1.69 amp. on the last step. The resistance consists of ten 10-ohm wire resistance units and one 100-ohm unit, which is cut in or out by a single-pole, single-throw switch. Single-pole switches are used to cut the rheostat out of the motor field circuit. In order to obtain the required capacity in the various steps at the least cost, the resistance units were purchased in the sizes shown in the accompanying table. It will be noted that the load on each unit is always considerably within its rated capacity.

The resistance units were mounted on an asbestos wood block, ⅜ in. thick, which is secured to the back of a maple panel. The arm and contact points were taken from an old, discarded rheostat.

The maximum normal shunt field current within the capacity of the rheostat is 9.75 amp. for a 115-volt motor, 6.75 amp. for a 230-volt motor, and 5.75 amp. for a 550-volt motor. Any shunt or compound wound motor having a normal field current not exceeding the values given can be safely handled, even on the first step of 10 ohms.

The cost of the material used was $16.40, and the cost of labor for assembling was $7.50.

J. M. WALSH.

Asst. Chief Engineer,
Gurney Elevator Co.,
New York, N. Y.

Resistance and Load Data of Rheostat Used for Testing D. C. Motor and Generator Fields

Step No.	Resistance Ohms	Rating Watts	Load	
			Amp.	Watts
1	10	270	5.00	250
2	10	189	4.10	168
3	10	144	3.50	122
4	10	108	3.03	92
5	10	90	2.68	72
6	10	75	2.40	58
7	10	60	2.17	47
8	10	45	1.98	40
9	10	45	1.83	34
10	10	45	1.69	29
Extra	100	361	1.69	290

New Equipment

for plant operation and maintenance

Industrial plant executives concerned with the selection and operation of mechanical and electrical equipment will be interested in these new devices which are designed to improve plant operation or reduce operating and maintenance costs.

Portable Electric Saw

THE Speedway portable electric saws, recently developed by the Electro-Magnetic Tool Co., 19th & 52nd Ave., Cicero, Ill., are made in two sizes; the Type 177 saw and the Type 178 saw.

The Type 177 saw is a 15-lb. tool which operates either a 6-in. or 7-in. blade that can be removed without the use of any tools by simply removing a nut. The 6-in. saw blade gives a maximum cut of 1¾ in. The 8-ft. extra tough rubber lead cord is furnished with a patented split plug. The no-load motor speed is 3,600 r.p.m. and this saw may be operated from any lighting socket, the motors being furnished for either 220, 110, or 32 volts.

Speedway portable electric hand saw.

The Type 178 saw is sturdier and heavier, weighing 22 lb. It is equipped with a ½-hp. universal motor, chrome nickel steel, heat-treated gears and ball bearings throughout. The 8-in. saw blade takes a 2¾-in. cut. The no-load speed is 1,500 r.p.m.

High Interior Reflector

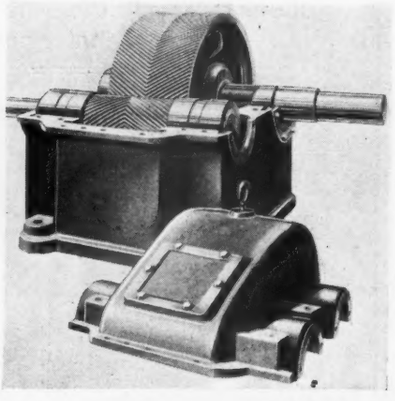
THE new Pittsburgh reflector No. I-1000, manufactured by the Pittsburgh Reflector Co., 304 Ross St., Pittsburgh, Pa., is designed particularly to meet the conditions existing in high industrial interiors where the lighting unit must be from 25 to 50 ft. or more above the floor, and for lighting through skylights. This reflector, which is of glass, silver plated, is said to be very concentrating, the bulk of the reflected light being confined within the 0-40-deg. zone, with a cut-off at approximately 60 degrees above the nadir. The maximum percentage of the reflected light flux reaches the work plane without striking the walls. These reflectors should not be installed at elevations less than 25 ft. for the 1,000-watt lamp and 20 ft. for the 750-watt lamp.

There is furnished with the reflector a porcelain mogul socket equipped with special casting at top, tapped for ½-in. conduit hanger and equipped with a special safety holder. The socket and holder are both supported from the casting, thus relieving the socket and electrical connections from any strain whatsoever. Provision is also made for using 300- and 500-watt lamps in this reflector when necessary.

New Pittsburgh No. I-1000 reflector

Continuous-Tooth Herringbone Speed Reducers

DEVELOPMENT of continuous-tooth herringbone gears for use in speed-reducing units has been announced by D. O. James Manufacturing Co., 1120 W. Monroe St., Chicago, Ill. A unit with the cover removed is shown in an accompanying illustration. Each individual tooth is brought to an apex and has the shape of a completed V. The tooth is not broken and the apex is not rounded to provide for tool clearance.



James continuous-tooth herringbone gear speed reducer.

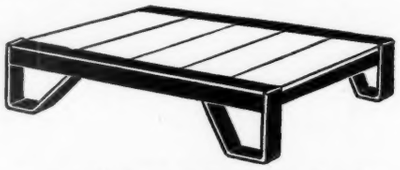
The teeth are of involute form and are cut with a 20-deg. pressure angle and a 30-deg. helix angle. Due to the continuous form, end thrust is neutralized. An overlap of approximately 50 per cent is obtained, so that the tooth action is smooth, continuous and noiseless, and no shock is produced when the load passes from one tooth to another, according to the manufacturer; two teeth are always in mesh in the plane of the axis.

It is said that the load is distributed over the full width of the teeth, and consequently large loads can be carried by small gears with high efficiency. For the same reason, greater reduction ratios can be obtained, together with higher rim speeds, longer life, and less power consumption; also less space is required because fewer reductions are necessary.

These continuous-tooth, herringbone gears are being built in reduction ratios ranging from 2:1 to 150:1, and for carrying loads from 2 to 200 hp.

Steel-Frame, Lift-Truck Platform

CONSTRUCTION and operating advantages of the new steel-frame, lift-truck platform or skid, shown in the accompanying illustration, are described by the manufacturer, Lewis-Shepard Co., Watertown Station, Boston, Mass., as follows:

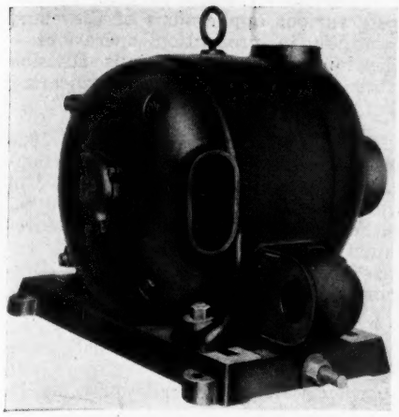


Arc-welded, steel frame on Lewis-Shepard lift-truck platform.

The clearance from the underside of the platform to the floor is the same on both sides and both ends, which permits a lift truck to be backed in under either side or either end. This new platform is steel bound all around; that is, all boards, in particular those at the ends, are protected by a steel binding. This extra armoring protects the end boards which must stand the bump of the lift truck when it is backed in under either end. The entire metal structure is arc-welded into the equivalent of one solid piece. It is stated that not a single hole is bored, and not a bolt or rivet is used in the entire platform. The top of the platform is flat. The steel does not extend above the boards nor the boards above the steel, which gives a flush top.

Inclosed Ventilated Motor

THE new Type EHJ motor has been especially designed by Fairbanks, Morse & Co., 900 South Wabash Ave., Chicago, Ill., for installation where fire prevention associations and insurance companies recommend the application of an inclosed motor on account of fire hazards from inflammable dust or explosive vapors. They are also intended to be used where the conditions of service are unusually severe, due to exces-



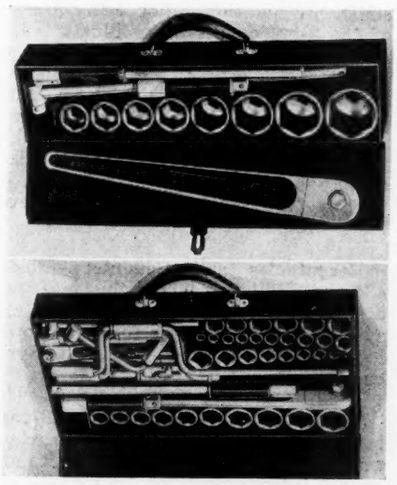
Fairbanks-Morse Type EHJ inclosed, self-ventilated motor

sive humidity and temperature, heavy dust, abrasive particles, and so on.

These machines, which are of the double-squirrel-cage type, are completely inclosed by rigid cast-iron frames without the use of any sheet metal covering. Flanged inlet and outlet openings are provided for the attachment of ventilating ducts. It is claimed that these machines have a starting torque of 200 to 250 per cent of that developed at rated load, with a starting current less than 450 per cent of full-load current. No centrifugal switches, variable resistances, or slip rings are required on these motors. The only external control equipment required is a properly fused, double-throw line switch.

Industrial Socket Wrench Sets

ANNOUNCEMENT is made by the manufacturer, The Husky Wrench Co., Twenty-seventh and Florence Sts., Milwaukee, Wis., of the marketing of new socket wrench sets especially selected for industrial use. Of these the Giant set is the most powerful set and is designed for heavy work around machinery and power plants. This is known as Set No. 512, and is shown in the lower of the accompanying illustrations. This set contains a 20-in. ratchet with heavy-duty No. 8 hexplug; combination tee 12 in. long; handy grip, 7 in. long; swivel extension, 17 in. long; and eight hexagon sockets for 1⅝- to 2⅜-in. nuts in the more commonly used sizes. This is packed in a steel carrying case and weighs 35 lb.



The Dual Husky socket wrench set (above) is a combination of a standard and heavy-duty set. The Giant set (below) is for very heavy work.

The No. 494 Dual set combines both Husky standard and heavy-duty sets conveniently arranged in a compact steel carrying case. A wide range of sockets and handles is included in this unit. The standard set contains, in addition to the various handles and extensions, 16 hexagon sockets from 7/16 to 1¼ in. and nine square sockets from ⅜ to 1 in. Ten hexagon sockets from 11/16 to 1⅝ in. are included with the heavy-duty equipment in this box. This set is illustrated in the upper of the accompanying illustrations.

Fifth-Wheel Trailer

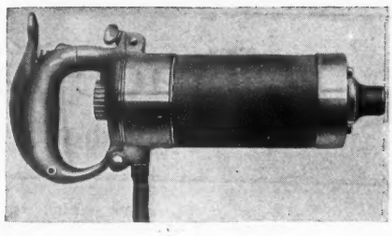
TRAILERS of the rubber-tired, fifth-wheel type have been developed by the Clark Tructractor Co., Buchanan, Mich. The tongue is used both for steering and for coupling one to the other, or directly to the tractor. The trailer is rated 3 tons capacity and is designed for handling bulky loads, it is said.

The platform is built of hardwood 1¼ in. thick, set flush with the frame. The corners are rounded and the ends are bound with 4-in. steel bands. Dimensions of the platform are 6 ft. 3 in. in length by 3 ft. in width. The platform is 20 in. high.

Full Hyatt bearing equipment is used on all wheels. The front wheels are 15 in. in diameter with 3½-in. face. The rear wheels are 18 in. in diameter with 3-in. face. Hard rubber truck tires are pressed on all wheels, but steel wheels can be furnished if desired. The axles are 1½ in. square, turned to 1 7/16 in. for the wheel spindles.

Electro-Magnetic Hammer

IMPROVEMENTS in the electro-magnetic Simbi model 26 hammer, shown in the accompanying illustration, are announced by The Fermot Co., 200 Broadway, New York, N. Y. This hammer is operated by hand and resembles a pneumatic hammer somewhat in size and shape. In operation an alternating-current solenoid actuates a movable plunger the recoil of which is governed by means of an adjustable helical spring. With 60-cycle current, the frequency of percussion is 7,200 strokes per minute. This hammer is used for drilling holes in concrete or stone, for chipping, beading, or calking. The new model hammer has the feed cable attached to the body of the hammer instead of to the handle, which, it is said, gives the operator more freedom of movement. Also, the aluminum housing that covered the body of the hammer in the old model has been eliminated to facilitate quicker cooling of the coil and incidentally has reduced the resounding humming which is caused by the high frequency of the vibration. It is stated that an increased efficiency of 30 per cent has been obtained in this new model. This hammer is distributed in the United States by the Rawlplug Co., Inc., 66 W. Broadway, New York, N. Y.



Improved Simbi model 26 electric hammer

Red Line Positive Printing Paper

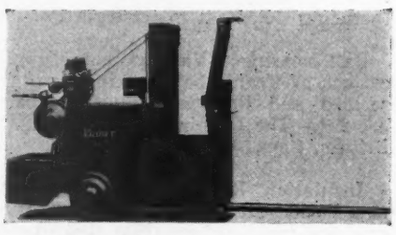
DEVELOPMENT and marketing of a positive-print paper with a dark-red or maroon line on a light-cream background, which is produced from the original tracing without the use of a negative, is announced by Eugene Dietzgen Co., 954 Fullerton Ave., Chicago, Ill. This carries the trade name of Ozalid printing paper.

Ozalid is printed in the same manner as are blueprints, but is developed dry by brief exposure to ammonia-water vapor. Because of this method of development it is said that the paper does not shrink or wrinkle and is true to scale, besides retaining its original strength. It is stated that the print produced is non-fading and can be shaded and colored, or written upon with pencil or ink. If prints are made on thin Ozalid paper they can be used for reproduction, it is said.

Hy-Lift Truck for Carrying Crates

RECENT adaptation of the Baker Hy-Lift truck for carrying large crates or similar packages has been announced by the manufacturer, The Baker-Raulang Co., Cleveland, Ohio. As the accompanying illustration shows, the carriage is fitted with two long forks in place of the usual platform and two clamps are provided in the upright section for securely holding either one or two packages by clamping at the top.

The clamping action is entirely automatic and takes place as soon as the truck commences to lift. One crate may be picked up and placed on top of another and then both of them carried on one load. In this case, and on high crates, the lower clamp drops back out of the way and the upper clamp comes into operation.



Adaptation of the Baker Hy-Lift truck for lifting and carrying crated goods.

Trade Literature

you should know about

Copies of literature which is described on this page can be obtained by writing to the manufacturer whose name and address are mentioned. It is always advisable to state the name and number of bulletin or catalog desired, as given in these columns.

Switches—Various types of Hubbell switches used for interior wiring are described and illustrated in Circular No. 277.—Harvey Hubbell, Inc., Bridgeport, Conn.

Tapered-Roller Bearings—An illustrated booklet describes the results of recent developments in the use of tapered-roller bearings as applied to machine tool equipment.—The Timken Roller Bearing Co., Canton, Ohio.

Warning Lights — New models of lanterns, illuminated sign and signal lights are illustrated in color in a 24-page booklet. — The Nichols-Lintern Co., 7960 Lorain Ave., Cleveland, Ohio.

Material Handling Equipment—Various applications of Cleveland tramrail systems in a foundry are illustrated in a leaflet.—The Cleveland Crane & Engineering Co., Wickliffe, Ohio.

Carbon Brushes—A 12-page catalog describes and illustrates various grades of Carenco brushes, besides listing other carbon products, giving instructions for ordering and price information.—Carbon Engineering Co., Milwaukee, Wis.

Graphic Meters—A heavy-duty meter element for use in d.c. meters and a quick-trip graphic instrument driven by a spring motor are described and illustrated in Bulletin 1126.—The Esterline-Angus Co., Indianapolis, Ind.

Motor Repair Equipment — Fiber fuse pullers, coil and wire tamping tools, feeler gages, wire insulation scrapers, and other maintenance and repair equipment are described and illustrated in a recent folder.—Grinder Sales Co., 526 West Fort St., Detroit, Mich.

Insulating Oil—A general discussion of the properties, with particular reference to dielectric strength, flash and fire points, of Universal Wemco C insulating oil is contained in leaflet 20,291.—Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

Ball Bearings—Various motor applications of Fafnir ball bearings are described and illustrated in a 30-page booklet.—The Fafnir Bearing Co., New Britain, Conn.

Insulation Resistance Testing—The new Pocket Manual of Megger Practice contains much information that should be helpful to users of Megger instruments and to others who are interested in the systematic testing of the insulation resistance of equipment. The contents of this manual includes insulation and measurement of its resistance, directions for various insulation tests, special directions for Megger testing, principle of operation and general instructions for using Megger instruments.—James G. Biddle, 1211 Arch St., Philadelphia, Pa.

Arc Welding — A 31-page booklet, S.P. 1767, deals with the arc welding of structural steel and gives a detailed description of the results of the tests conducted on welded joints at the Carnegie Institute of Technology.—Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

Grounding Devices — Loose-leaf sheets give the standard grounding rules and regulations adopted by the State of New Jersey and show by sketches the approved methods of using Groundulets for this purpose.—Groundulet Co., 480 Broad St., Newark, N. J.

Industrial Thermometers — The revised edition of catalog 625A devotes 48 pages to a description and discussion of the various industrial thermometers manufactured by this company. In this catalog particular care has been taken to show the various types, shapes and forms of these thermometers to facilitate ease and accuracy in ordering this equipment.—C. J. Tagliabue Mfg. Co., 18-88 Thirty-Third St., Brooklyn, N. Y.

Portable Elevators — Bulletin 90-D describes the Revolvator electric portable elevator with worm-gear drive and illustrates its special features.—Revolvator Co., 336-352 Garfield Ave., Jersey City, N. J.

Corduroy Cranes—Bulletin 42X gives numerous illustrations of the work performed in industrial plants by P & H corduroy cranes, and also shows their construction. — Harnischfeger Corp., Milwaukee, Wis.

Air-Cooled Transformers — Bulletin 1026 describes and gives prices on the line of Sorgel air-cooled, dry-type transformers. This line consists of single-phase, 110/220-volt transformers up to 30 kva., three-phase transformers to 50 kva., balance coils, new code lighting transformers, insulating transformers, auto-transformers, welding transformers, and transformers for special applications. It is stated that this equipment has been especially designed for high efficiency and maximum ease of installation.—Sorgel Electric Co., 91 W. Water St., Milwaukee, Wis.

Tramrails—A series of folders illustrate various applications of Cleveland tramrails in production operations.—Cleveland Electric Tramrails Division of the Cleveland Crane & Engineering Co., Wickliffe, Ohio.

Flexible Couplings — Bulletin 1026 describes the Nicholson flexible coupling, which is an all-metal coupling in which the two flanges are coupled together by floating steel keys in dovetailed slots. The entire coupling is encased.—W. H. Nicholson & Co., 12 Oregon St., Wilkes-Barre, Pa.

Cast-Iron Pulleys—A series of circulars discuss the quality of castings in Pyott Red-Face cast-iron pulleys and fly wheels.—Pyott Foundry Co., 328 N. Sangamon St., Chicago, Ill.

Chain Block — A circular describes the new Morris Gravity-Lowering chain block which is made in various capacities from ½ to 5 tons and, it is stated, saves 90 per cent of the time spent in lowering loads.—Herbert Morris, Inc., Buffalo, N. Y.

Monorail Equipment — A folder describes the American monorail equipment, which includes a special rail mounting and support, trolleys for special purposes, switches, and ball-bearing trolley wheels for replacement on other systems. — The American MonoRail Co., W. Sixty-Seventh Street and Pear Ave., Cleveland, Ohio.

Electric Hammer—A folder describes some of the many uses of the Ajax electric hammer, which weighs 10 lb. and is said to deliver 2,400 blows per minute. This may be used for cutting concrete, stones, trimming castings, or other work.—Ajax Electric Hammer Corp., 117 W. Sixty-Third St., New York, N. Y.

Speed Reducer—A circular describes the Morrison speed-reducing transmission which is of the spur-gear reduction type in which the driven spindle may be adapted to a desired height by loosening a clamp screw and moving the spindle in a complete circle so that it will line up directly with the driving shaft. In addition, other transmissions of the 2-hp. capacity are illustrated.—Morrison Machine Co., Paterson, N. J.

Flexible Coupling—A bulletin illustrates the various Climax universal joints for propeller shaft assembly and power transmission, and flexible couplings of the cord-disk type. — Climax Motor Appliances, Inc., Cleveland, Ohio.

Receptacles and Condulets—Folder 43 and Bulletin 2093 illustrate and describe a line of plug receptacles and safety switch condulets for light power requirements.—Crouse-Hinds Co., Syracuse, N. Y.

Handbook on Gearing — A 78-page book entitled "Blue Book on Gearing" gives considerable engineering data and other information on rawhide, cut metal, planed bevel, herringbone, spiral and worm gears and racks.—The Horsburgh & Scott Co., 5110 Hamilton Ave., Cleveland, Ohio.